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Body fat measurements: evaluating obesity and overweight in adolescents

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- *Body fat measurements: evaluating obesity and overweight in adolescents.*
- *Obesity and overweight: their role in blood glucose and insulin levels in adolescents.*

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ABBREVIATIONS

AUC: Area under the curve
BF%: Body fat percentage
BMI: Body mass index
CDC: Centers for Disease Control and Prevention
CI: confidence interval
DEXA: dual-energy X-ray absorptiometry
EPITeen: Epidemiological Health Investigation of Teenagers in Porto
g/mm^2: Grams per millimetre square
HBSC: The Health Behaviour in School-aged Children
HDL: High-density lipoproteins
HOMA: Homeostasis model assessment
IMC: Índice de Massa Corporal
IOTF: International Obesity Task Force
Kg/m^2: Kilograms per meter square
KIDMED: Mediterranean Diet Quality Index
LDL: Low-density lipoprotein
mm: millimetres
mmol/L: millimoles per liter
mU/ml: mili-Units per mili-liter
MRI: Magnetic resonance imaging
NHANES: National Health and Nutrition Examination Survey
NCHS: National Center for Health Statistics
NLR: Negative likelihood ratio
NPV: Negative predictive value
OR: Odds ratio
P_{75}: Percentil 75
PLR: Positive likelihood ratio
pmol/L: picomoles per liter
PPV: Positive predictive value
SD: Standard deviation
SPSS: Statistical Package for the Social Sciences
US.: United States
WHO: World Health Organization
WHtR: Waist to height ratio

RESUMO

Introdução: Nas últimas duas décadas a prevalência de excesso de peso e obesidade na Europa, em adultos triplicou. Esta tendência também se verifica em crianças e adolescentes, sendo que os países do Sul da Europa apresentam uma maior prevalência de excesso de peso quando comparados com outros países da Europa.

Contudo, a inexistência de um consenso internacional sobre como medir excesso de peso e obesidade torna difícil a comparação entre dados de prevalência de diferentes estudos longitudinais, assim como a correta identificação das suas tendências.

Os adolescentes com excesso de peso e obesidade apresentam maior morbilidade do que os que não têm excesso de peso, sendo que as patologias mais associadas ao excesso de peso são a insulinoresistência e a secreção diminuída de insulina.

Objectivos: Este trabalho teve como objetivo estudar quais as medidas antropométricas que contribuem para o diagnóstico de excesso de peso e obesidade e o contributo destas medidas na identificação precoce de adolescentes com alterações do metabolismo da glicose. De acordo com os seguintes objetivos específicos:

1) avaliar a capacidade de diferentes medidas de gordura corporal para identificar adolescentes de 13 anos com excesso de peso e obesidade, identificando quais os respetivos valores de corte;

2) avaliar a capacidade de diferentes medidas antropométricas para identificarem adolescentes de 13 anos com valores elevados de glicose, insulina e HOMA.

Métodos: A investigação foi realizada no âmbito da Coorte EPITeen (*Epidemiological Health Investigation of Teenagers in Porto*), constituída por adolescentes nascidos em 1990 e inscritos nas escolas públicas e privadas da cidade do Porto durante o ano lectivo 2003/2004 foram recrutados e avaliados (proporção de participação de 78%).

A informação foi recolhida através de dois questionários auto aplicados (um preenchido em casa e outro na escola), recolhendo informação sobre a história individual ou familiar de doença e características sociais, demográficas e comportamentais. Na escola, foi realizado também um exame físico, por uma equipa experiente de enfermeiros, nutricionistas e médicos. Para além do peso e da altura, o perímetro da cintura, as pregas cutâneas bicipital e tricipital foram também medidos. Foi colhida uma amostra de sangue após um jejum nocturno de 12h. Os valores de glicose plasmáticos foram avaliados usando os métodos enzimáticos habituais e a insulina foi medida pelo método de radioimunoensaio. A insulinoresistência foi calculada pelo método de modelo de homeostase (HOMA-IR), com base na glicemia de jejum e as concentrações de insulina: HOMA-IR=insulina(mU/ml)*glicose(mmol/L)/22,5.

Na comparação de médias foi usado o teste de Wilcoxon-Mann-Whitney e para analisar as relações entre as diferentes medidas antropométricas e o Índice de Massa Corporal (IMC) assim como com a glicose, insulina e HOMA foi usado o coeficiente de correlação de Spearman. O valor diagnóstico das diferentes medidas de adiposidade foi calculado através da análise das curvas ROC (receiver-operating characteristic). A área por baixo da curva (AUC) também é apresentada.

Resultados: Na nossa amostra a prevalência de excesso de peso (IMC≥85th) foi de 11.9% nos rapazes e de 12.4% nas raparigas.

O IMC correlacionou-se positiva e significativamente com todas as medidas antropométricas em ambos os sexos. Nos rapazes a correlação encontrada mais forte foi com o perímetro da cintura, quer nos adolescentes com IMC<85th quer nos adolescentes com IMC≥85th. Nas raparigas a correlação mais forte encontrada foi com a percentagem de massa gorda para as que têm IMC<85th [0.79(IC 95%: 0.77; 0.82)] e com o perímetro da cintura para as raparigas com IMC≥85th [0.71(IC 95%: 0.59; 0.80)]. Usando o percentil 75 (P_{75}) como valor de corte, o perímetro da cintura foi a medida antropométrica que melhor identificava adolescentes com IMC≥85th. A sensibilidade foi de 100% para os rapazes e de 97.6% (IC 95%: 94.9-100) para as raparigas. A especificidade foi de 85.5% (IC 95%: 83.1-87.9) e 85.5% (IC 95%: 83.5-88.1). Quando se usou o rácio perímetro da cintura/altura estes valores foram de 86.7% (IC 95%: 80.5-93.0); 86.3% (IC 95%: 80.2-92.3) para a sensibilidade, e 92.9% (IC 95%: 91.2-94.7); 94.8% (IC 95%: 93.3-96.2) para a especificidade.

Em ambos os sexos todas as medidas antropométricas se correlacionaram de forma positiva e significativa com a insulina e HOMA. Para as raparigas a medida antropométrica que melhor identifica adolescentes com valores de insulina e HOMA≥P_{75} foi o rácio perímetro da cintura/altura: a sensibilidade foi de 66.7% (IC 95%: 59.4-73.9) para a insulina e 60.2% (IC 95%: 52.7-67.8) para a HOMA; a especificidade foi de 59.2% (IC 95%: 54.8-63.6) e 60.7% (IC 95%: 56.4-65.1) respetivamente. Entre os rapazes a medida antropométrica mais precisa para identificar os que se encontravam ≥P_{75} foi o IMC: a sensibilidade foi de 66.4% (IC 95%: 58.9-74.0) para a insulina e de 65.6% (IC 95%: 58.0-73.1) para a HOMA; a especificidade foi de 62.5% (IC 95%: 58.1-67.0) e 62.2% (IC 95%: 57.7-66.6) respectivamente.

Conclusões: Para além do IMC, o perímetro da cintura demonstrou ser uma ferramenta específica na identificação de adolescentes com excesso de peso. Adicionalmente o uso do rácio perímetro da cintura/altura pode melhorar a especificidade desta medida.

O IMC, o rácio perímetro da cintura/altura e o perímetro da cintura revelaram-se também medidas precisas na identificação de adolescentes em risco de alterações do metabolismo da glicose.

ABSTRACT

Introduction: In Europe, the prevalence of overweight and obesity in adults has tripled in the last two decades. This trend is also observed in children and adolescents, having the countries of southern Europe a higher prevalence of overweight compared with other countries in Europe.

However, the inexistence of an international consensus about how to measure overweight and obesity makes the comparison of cross-sectional prevalence data difficult, as well the clear identification of its trends.

Overweight and obese adolescents have high morbidity than non-overweight adolescents, with insulin resistance and impaired insulin secretion being the most common pathologies associated to overweight.

Objectives: This research aimed to study the anthropometric measures that can contribute to the evaluation of overweight and obesity, and the role of these measures identifying adolescents with alterations on the glucose metabolism through the following specific objectives:

1) to evaluate the ability of different body fat measures to identify overweight and obesity in 13-year-old adolescents and to identify the best cut-offs of these measures; 2) to evaluate the ability of different adiposity measures to identify 13 year old adolescents with high values of glucose, insulin and HOMA.

Methods: Eligible participants were urban adolescents, members of the Epidemiological Health Investigation of Teenagers in Porto (EPITeen). The EpiTeen is a population-based cohort of adolescents born in 1990, which were recruited from private or public schools in Porto in the 2003/2004 school year (78% participation at the individual level). Data were collected using self-administered questionnaires, comprising information on clinical, behavioural, social and demographic characteristics. A physical examination was also performed at school, by a team of experienced nurses, nutritionists and physicians. Beyond weight and height, waist circumference and bicipital and tricipital skinfolds thickness were measured. A 12-hour overnight intravenous blood sample was taken from an antecubital vein. Blood glucose was measured using automatic standard routine enzymatic methods and insulin was measured by radioimmunoassay. Insulin resistance was assessed by the homeostasis model method (HOMA-IR), based on fasting glucose and insulin concentrations: HOMA-IR=Insulin (mU/ml)*glucose (mmol/L)/22.5. To compare means we used the Wilcoxon-Mann-Whitney and to examine relations between the different anthropometric measurements with BMI, and the relations between the anthropometric measures and glucose, insulin and HOMA we used Spearman correlation coefficient. The diagnostic

value of the different measures of adiposity was calculated through the receiver-operating characteristic (ROC) curve analyses. The area under the curve (AUC) is also presented.

Results: In our sample the prevalence of overweight (BMI≥85th) was 11.9% in boys and 12.4% among girls.

BMI was positively and significantly correlated with all anthropometric measures, in both genders. In boys the stronger association was found with waist circumference, both in adolescents with BMI<85th and ≥85th. In girls, the stronger association was found with body fat percentage for those with BMI<85th [0.79(95% CI: 0.77; 0.82)] and with waist circumference among those with BMI≥85th [0.71(95% CI: 0.59; 0.80)]. Waist circumference, using the 75th percentile as cut-off, was the anthropometric measure that better identified adolescents with BMI≥85th percentile. Sensitivity was 100% in boys and 97.6% (95% CI: 94.9-100) in girls; specificity was 85.5 %(95% CI: 83.1-87.9) and 85.8% (95% CI: 83.5-88.1). When the waist to height ratio was used those values were 86.7% (95% CI: 80.5-93.0); 86.3% (95% CI: 80.2-92.3) for sensibility, and 92.9% (95% CI: 91.2-94.7); 94.8% (95% CI: 93.3-96.2) for specificity.

In both sexes all of the anthropometric measurements correlate positively and significantly with insulin and HOMA. Among girls, the best anthropometric measure to identify adolescents with values of insulin and HOMA above the 75th percentile was waist to height ratio: sensitivity was 66.7% (95% CI:59.4-73.9) for insulin and 60.2% (95% CI:52.7-67.8) for HOMA; specificity was 59.2% (95% CI:54.8-63.6) and 60.7% (95% CI:56.4-65.1), respectively. Among boys the best anthropometric measure to identify those above the 75th percentile was BMI: Sensitivity was 66.4% (95% CI:58.9-74.0) for insulin and 65.6% (95% CI:58.0-73.1) for HOMA; specificity was 62.5% (95% CI:58.1-67.0) and 62.2 (95% CI:57.7-66.6), respectively.

Conclusions: Beyond BMI, waist circumference demonstrated to be a sensitive and specific tool for the detection of overweight in adolescents. Additionally, the use of the waist to height ratio may improve the specificity of this measure.

Furthermore, BMI, waist circumference and waist circumference to height ratio revealed to be accurate in the identification of adolescents at risk of alterations in the glucose metabolism.

INTRODUCTION

OVERWEIGHT AND OBESITY

Prevalence of overweight and progression over life time

Obesity is an epidemic of the century, one of the most serious public health problems around the world and more worrisome than the classic questions such as malnutrition, and infectious diseases (1, 2). The prevalence of overweight and obesity has increased in adults in several countries (3, 4) and in school aged children since 1980 (5). However in some countries the increase appears to stop, or even start decreasing, the burden is still very high.

In Europe the prevalence of obesity and overweight in adolescents has tripled in the last two decades, with the prevalence at 13-years-old in 2001/2002 to 14.4% in boys and 9.3% in girls (6).

Limited longitudinal data are available for children and adolescents. The Health Behaviour in School-aged Children (HBSC) presented a prevalence of overweight among adolescents since 1997 (7) and compared to those in 2005-2006 survey (8) showed a decrease in the prevalence of overweight among males and an increase among females. However, it is important to notice that in this study the prevalence of overweight is estimated based on self-reported weight and height (8). One study on children aged 7-9 years found that the prevalence of overweight according to IOTF cut-offs was 20.3% and the prevalence of obesity 11.3% (9). Comparing these results with the results of two studies, one in 1970 (10) and other in 1992 (11) it is possible realize that Body Mass Index (BMI) of Portuguese children have been increasing in last decades.

More data is available from cross-sectional studies. The Pro Children Survey, realized in 2003 on 11-year-old children, in Portugal was found an overweight prevalence of 26.5% among males and 17.7% among females and the prevalence of obesity was 2.2% among females and 6.2% among males (using the IOTF criteria) (12). Similar results were found in the first evaluation of the EPITeen project (Epidemiological Health Investigation of Teenagers in Porto), held in 2003-2004 school-year, in which the prevalence of overweight in adolescents aged 13 years was 18.8% among females and 20.8% among males and the prevalence of obesity was 5.7% among females and 6.6% among males (13). In the evaluation of the HBSC held in 2005-2006 the prevalence of overweight in 13-year-old adolescents was, respectively among males and females, 12.5% and 22.8% and in 15-year-old adolescents it was 14.3% and 20.8% (8). Higher values were found in 2008 from a population-based study of Portuguese adolescents (11-15 years) reported that the national prevalence of overweight was 28% and the estimate of obesity was 11% (14). This study also reported the northern region as having the highest prevalence of overweight (overweight + obesity), according with Center for Disease Control and Prevention (CDC) classification, however the difference for other regions did not reach statistical significance (14).

Thus, despite the inexistence of systematic data on BMI in Portugal, the data available allow us to recognize that our country seems to present one of the higher prevalence of overweight/obesity in Europe (7, 8, 12) and apparently increasing.

BMI levels track throughout lifetime (15) and the effects of childhood obesity are reflected in adulthood morbidity and mortality (2, 16, 17). Adolescence has been referred as a critical period for the development of co-morbidities related to obesity in both sexes (2, 6).

As analysed by Guo and colleagues (18), the higher the BMI is in childhood, higher is the probability to be an obese adult. They analysed the probability of having a BMI ≥ 30 kg/m^2 at 35 years old, and the probability of becoming an obese adult increases as obesity tracks out to childhood. For girls at the 95th percentile during childhood to become obese as adults, increases from 40% at 3 years old to more than 60% at 12 to 20 years old. In boys at the same percentile the probability increases from less than 20% at 3 years old to more than 60 % from 17 to 20 years old.

For overweight boys and girls (85^{h} percentile) the probabilities of being obese adults were lower. For girls the probability varies from 20 to 39.9% from 4 to 18 years of age until 40-59.9 % after 18 years of age. In boys the probabilities vary from less than 20% from 3 to 17 years of age, until 20-59.9% after 18 years of age. This data suggest that if an individual in his adolescence has a moderately or high BMI, has a high probability of become an obese adult.

The outcomes of childhood and adolescence overweight and obesity are several. They have been associated with increased health risks and morbidities, namely cardiovascular diseases, higher rates of mortality in adulthood, besides the adverse socioeconomic outcomes (19-23).

Adolescence as a critical period for overweight

Throughout human development, there are four critical periods for the development of overweight and obesity: intrauterine, infancy, mid-childhood and adolescence (24). Also, in the last decades the hypothesis that factors acting in pre- and early postnatal life were associated with the occurrence of adult diseases, have emerged (2, 25) and a strong evidence was found regarding cardiovascular diseases, obesity and diabetes (26, 27).

In infancy research made in children at risk of overweight revealed that this development was associated with an increased risk of Diabetes in childhood (28). Most of these results became from research on children who were small for gestational age at birth or suffered from intrauterine growth retardation. However, yet in children who had an appropriate birth weight for gestational age the rapid infant growth was significantly associated with higher risk for obesity and type II diabetes compared with children without a rapid growth (28, 29).

During childhood, the amount of fat mass increases at the first year of life and then it decreases at about six years old to increase again in later childhood. The period when adiposity reaches the minimum value, which occurs at approximately 6 years of life, is known as "adiposity rebound" (30). An adiposity rebound earlier in the child development increases the risk of higher values of BMI in adolescence (30).

Adolescence is the transitional period between childhood and adulthood that begins with puberty (2). In this period occur changes in body composition and body size. It is a development period with particular morphologic and physiological changes. Since what we intent classifying subjects as overweigh or obese is identify those with excess of body fat and none, classifying an adolescent as obese or overweight can be problematic because of the changes that occur at this stage, particularly in relation to sexual maturation, body composition and fat mass distribution. This problem became higher because we need to take in account the gender differences during this period of life.

In adolescence the boy's percentage of lean mass increases and the percentage of fat mass in the total weight diminishes, in contrast with girls (31). Fat distribution in boys suffers more changes between pre puberty and late puberty when compared with girls, with late pubertal boys having a more android fat distribution (32). While girls accumulate greater amounts of fat during adolescence, but less centralized pattern, with an enlargement of hips and a decrease in waist to hip ratio (33, 34).

Defining overweight and obesity

Obesity and overweight are considered public health problems; they need to be monitored in children and adolescents. For adults cut off values for BMI from which we could define overweight and obesity are well defined. In children and adolescents this classification is not consensual worldwide, as there are several classifications in use (2, 16, 35-38).

Most of the classifications commonly use the BMI which relates the weight in kilograms to height in meters using the formula: BMI=weight/(height) ^{2}. As weight and height are simple, non-invasive and almost inexpensive to obtain, the BMI became a simple and inexpensive index.

In adults the cut-off points to classify them as overweight (25 kg/m^2) or obese (30 kg/m^2) are widely accepted since they are based on the risk of disease associated with each BMI category. However, in children and adolescents, the negative consequences of overweigh frequently occurs later in life, namely during adulthood. So, the establishment of a clear cause-effect association is difficult. Thus the definitions of obesity in this age range are mostly based in statistical methods.

The criteria of the CDC is based on percentile curves developed from a nationally representative survey of United States and used the 85th and 95th percentiles as cut off points for overweight and obesity (36). The criteria of the International Obesity Task Force consists of age and sex specific cut off points for BMI obtained from percentile curves drawn that at 18 years passed through the cut off points of 25 Kg/m^2 and 30 Kg/m^2 for adult overweight and obesity (35). These curves were based on data from six nationally representative cross-sectional growth studies (Brazil, Great Britain, Hong Kong, Netherlands, Singapore and United states). Additionally, as a tentative to create a more generalizable data, in 2006 the World Health Organization (WHO) published WHO Child Growth Standards for children from 0 to 5 years (39) derived from a longitudinal follow-up from birth to 24 months and a cross-sectional survey of children aged 18 to 71 months, from widely cultural settings (Brazil, Ghana, India, Norway, Oman and USA), whose caregivers follow internationally recognized health recommendations. In 2007, WHO also published the growth references for school-aged children and adolescents, from 5 to 19 years (38) based in data from the 1977 National Center for Health Statistics (NCHS)/WHO growth reference (1-24 years), merged with data from the under-fives growth standards' cross-sectional sample (18-71 months) to smooth the transition between the two samples. So, we have at least three different and widely used criteria.

Beyond the cut-off problem in the definition of overweigh and obesity, use BMI as measure to posterior classification adds additional problems since it does not take into account if the rated weight is muscle mass or fat mass (15, 19) or distinguishes between different fat distributions. Additionally, by gender and throughout development there are considerable changes in BMI because of the substantial changes of body fat, making impossible identify a cutt-off value equal for all ages (2, 15, 19).

Besides the problem of attributing the right cut off points, there is also a need to standardize the classification, some authors refer to overweight including obese and overweight individuals and others make this discrimination. So to avoid any misunderstandings in this paper when we refer to overweight adolescents we are including obese and overweight adolescents.

The body fat distribution and the different health effects

The outcomes of childhood and adolescence overweight and obesity are several. Studying the effects of overweight and obesity in childhood and adolescence is without any doubt an important subject of study. However, besides the fact of being overweight or obese is also important to take into consideration the fat distribution and its outcomes.

In adults the role of fat distribution and the predisposition for diabetes, cardiovascular diseases and atherosclerosis (40, 41) is recognized, many studies report that body fat distribution is a best indicator of risk factors and mortality than BMI (42-44). Data from the Amsterdam Growth and Health Longitudinal Study refer that trunk fat is adversely associated with large arterial stiffness, while some degree of protection is conferred by peripheral fat and lean mass (45).

Trunk accumulation of fat particularly is related with more adverse health related outcomes than peripheral fat (46). Moreover not all of the peripheral fat seems to have a protective role subcutaneous fat at the trunk seems to have an adverse effect on cardiovascular risk, increasing arterial stiffness (47).

Visceral adipose tissue and subcutaneous adipose tissue are components of the abdominal obesity (48), it is known that these two components have morphological and functional differences although the determinants of visceral adipose tissue in children are still being studied (32).

Some authors report that in adolescence visceral adipose tissue represents less 10% of the total abdominal fat, more than 90% is represented by subcutaneous adipose tissue (49). This could suggest that, at this stage of development, the impact of visceral fat deposition on metabolic parameters is likely to be small, but a large set of studies found abdominal fat as a cardiovascular risk factor and similarly to adults the deposition of visceral adipose tissue is known to increase with age (32).

It was first described in the 20^{th} century by Vague that individuals with a central fat distribution were at greater health risk when compared with those with peripheral fat (50). The risk of cardiovascular diseases seems to be equal for adults and adolescents, although BMI, as an indicator of total fat is also considered a predictor of cardiovascular diseases other anthropometric measures (waist circumference and waist to height ratio) seem to be able to identify adolescents at risk (51, 52). As measure of this type of fat, an increased waist circumference seems to be associated in children with abnormal blood pressure values, elevated serum levels of cholesterol, low-density lipo-protein, triglyceride and insulin, as well as lower concentrations of HDL (53, 54).

The best way to access visceral adipose tissue in children is through computed tomography and Magnetic Resonance Imaging (MRI) (55). But these are expensive and not always easy to access methods for the determination of the deposition of visceral adipose tissue.

Indirect measures to determine the deposition of visceral adipose tissue are the X-ray absorptiometry dual radiation (DEXA) however this form of evaluation has the limitation of not distinguishing subcutaneous form intra abdominal fat mass (56). Waist circumference as been also referred as an indirect measure of visceral adipose tissue Bouchard (57) in the HEalth, Risk factors, exercise Training and Genetics (HERITAGE) Family Study and the Quebec Family Study stated that waist circumference is very strongly correlated with BMI (r 0.93) and fat mass (r 0.92). These results show that each of these indicators (BMI; waist circumference and fat mass) can be useful as an indirect measure of visceral adipose tissue. One other way to access indirectly visceral adipose tissue are the trunkal skinfolds as stated by Fox and colleagues (58) in children aged 11-13 years old, they reported that abdominal skinfold as an acceptable indicator of abdominal adiposity (r 0.54–0.70).

Caprio and colleagues (59) were ones of the firsts studying the relationship between visceral adipose tissue and adverse health outcomes in adolescents. In their sample of 18 girls aged 10-16 years old, they found that in obese girls (classified by the authors according to the First National Health and Nutrition Survey as ≥95th percentile), intra-abdominal fat but not BMI or waist-to-hip ratio was highly correlated with basal insulin ($r=0.55$, $P<0.04$), triacylglycerols ($r=0.53$, $P < 0.03$), and high-density-lipoprotein (HDL) cholesterol ($r=-0.54$, $P<0.04$).

More recently Syme and colleagues (60) in their study involving a sample of 324 adolescents, 12-18 years old in Canada, stated that among children being overweight or obese stated that visceral adipose tissue was significantly related to risk factors for the metabolic syndrome. However, such association was not observed in the case of subcutaneous adipose tissue as well as total fat mass (60).

Subcutaneous adipose tissue depots occur frequently when there is a high caloric diet with limited physical inactivity. It acts as a metabolic deposit where excess free fatty acids and glycerol are stored as triglycerides in adipocytes (48). When there the storage capacity is exceeded, if there is chronic stress, or if there is some genetic predisposition that impair the ability to generate new adipocytes fat accumulates in other areas outside the subcutaneous tissue (61) inducing metabolic alterations that can lead to type 2 diabetes (62).

Abdominal fat in adults is associated with inflammatory responses increasing the cardiovascular risk, in fact central fat seem to be more correlated with cardiovascular risks than peripheral fat (as the fat depots in the limbs) (45, 63).

Some authors report the same association in female adolescents; they report that the white blood cells count (inflammatory marker) is positively related to abdominal adiposity in female obese adolescents. This relationship was more distinguishable with subcutaneous than visceral adipose tissue (64).

So there is a need to know which methods should one use to measure body fat in children and adolescents and which ones can help to estimate from an easy and inexpensive way the different forms of body fat distribution.

Different methods to access body fat

Several methods may be used to calculate body composition in adolescents: the underwater weights that measures body density, from witch fat and lean mass content are estimated by assuming standard figures for the density of these components (65), the ultrasound, DEXA, are considered reference methods because of its precision (66, 67). However, these methods are more expensive and difficult to access (68) than the assessment weight, height, skinfolds or even bio-electrical impedance (66).

The evaluation of anthropometric measures and bio-electrical impedance are the most widely used methods in clinical settings when the population size is big, when there is a need of a quick and easy to access measurement and when there are few economic resources (66, 69).

Bio-electrical impedance measures the opposition of body tissues to a small alternating current that is imperceptible to the subject. Its reliability is generally high an can approach for those that use height and weight (70). With the introduction of the foot-to-foot bio-electrical impedance that only require the children or adolescent to step on scales with electrode foot plates, this method has become more used because the children under evaluation do not need to lay quietly supine for the procedure. However there is still a lack of reference data and equations so that its use can be more accurate (71).

BMI is the most common indicator used to identify obesity and overweight in most o f the settings (clinical, community based programs and public health). It is attractive to use BMI because it depends on the evaluation of two anthropometric measures, weight and height (BMI=weight/height^2) that are the ones more commonly collected on children worldwide (71).

In order to use BMI as a reliable indicator of body fat is also important to make an accurate measure of height and weight. If it is possible height should be measured at the nearest 0.1cm if possible with a stadiometer mounted on the wall or a portable stadiometer that allows to position properly the child or adolescent with the back against a vertical surface. Stadiometers attached to scales that do not allow the child or adolescent to be correctly positioned are not recommended. Weight should be measured by using a good quality scale to the nearest 100g. In a research setting, when choosing the equipment it should be one that allows maximum consistency over time and reliability between observers taking measurements. It should be always considered by the investigators the regular calibration of the equipment because with the repeated use and the transportation the equipments should be checked frequently (71).

The accuracy of BMI varies substantially according to the degree of body fatness, among relatively fat children BMI is an good indicator of excess adiposity, but differences in the BMIs of more thinner children can be due to differences in fat free mass (CDC percentile, BMI for age<85th) (15).

Therefore the need to use other body fat measures arose. Most of the anthropometric measurements used assume the principle that the body has two different compartments, the fat mass and the fat-free mass. Anthropometric measurements should be fast and non-invasive (72).

Skinfold thickness determination alone or in association with limb circumference measurements are frequently used to estimate the percentage of body fat. They estimate the size of subcutaneous fat depot; which in turn provides an estimate of total body fat. The relationship between subcutaneous and internal fat is nonlinear, lean subjects have a smaller proportion of body fat deposited subcutaneously than obese subjects (72).

The measurement of single skinfold or a set of skinfolds is an estimate of subcutaneous fat which in turn gives us an estimate of total fat mass (19, 72). They are non-invasive measures, relatively easy to apply in field studies, but they require a trained evaluator for the measurement to be reliable (15, 19). Skinfold thickness measurements are best when made by precision thickness callipers. The most commonly used sites are: triceps skinfold(is measured at the midpoint of the back of the upper arm), biceps skinfold(is measured on the front of the upper arm, directly above the centre of the cubital fossa, at the same level as the triceps skinfold); subscapular skinfold (is measured below and laterally to the angle of the shoulder blade); suprailiac skinfold (is measured in the mid-axillary line immediately superior to the iliac crest) and the midaxillary skinfold (is picked up horizontally on the midaxillary line) (73).

They can provide a more accurate measure of body fat, by identifying subcutaneous fat, better than BMI according to age (15, 74). However there is still small evidence that sustain the evaluation of skinfold thickness once BMI is known, because their evaluation seems to bring no additional information regarding total body fat or other risk factors (19) and they require a trained evaluator for the measurement to be reliable (15).

From the existing anthropometric measures, there are measurements that allow estimating central and visceral fat like waist circumference or their derivate indices; it is believed to be an indicator of central, upper body adiposity. An accurate measure of waist circumference can be used in adults and children, an indicator of a deviation from normal weight and to health risks assessment (19, 75). Although the evaluation of waist circumference may be influenced by spinal curvature and posture and the amount of abdominal musculature, this anthropometric measure seems to have a similar performance to BMI to access overweight and obese adolescents (67) and it is also inexpensive and easy to use.

Comparisons between measurements of body fat made trough MRI report that waist circumference in children when compared with BMI can provide a better estimate of visceral fat (76). Especially for adolescents waist circumference can perform as an important predictive indicator of health risks (19). Nevertheless there is a need to identify waist circumference cut off points that can identify children and adolescents at risk of cardiovascular or metabolic problems that have already been classified as obese or overweight trough BMI (19).

More recent studies also mentioned waist to height ratio as an index of abdominal obesity that seems to be correlated with various metabolic complications as it is BMI (77) furthermore the authors suggest that an single cutt-off point of 0.5 can be used to identify children and adults at increased risk (51).

As there are several measures and the BMI is used widely to define obesity and overweight in children and adolescents, there is a need to evaluate how other body fat measurements complement the information given by BMI and improve the sensitivity and specificity to detect overweight and obesity in adolescence. And try to complement the existing information regarding cutt-off points that are more appropriate to identify children with the most visceral fat or greatest risk for cardiovascular and metabolic problems (19).

GLOSE METABOLISM

Obesity and overweight as a risk factor for hyperglycemia and insulin levels in adolescents

Children with high levels of BMI are more likely to become obese adults, when compared with thinner children (78). So overweight and obesity in childhood and adolescence have short term and long term consequences, high levels of BMI have been associated with cardiovascular risk factors such dyslipidemia, increased blood pressure and insulin resistance (15, 79, 80).

Metabolic syndrome is characterized by increased concentrations of triglycerides, decreased concentrations of low-density cholesterol (HDL), increased blood pressure, increased waist circumference and increased levels of glucose (81). When an individual appear associated with three of these five risk factors we can establish the diagnosis of metabolic syndrome (81, 82).

Nowadays, it is known that this kind of aggregation starts early in life. However, in adolescents there is an additional difficulty finding the correct diagnostic cut off value of metabolic disorders, because of the variability that exists on values trough growth and development (83).

These metabolic derangements predict type 2 diabetes and coronary artery disease (82) and in parallel with the increase of metabolic syndrome and obesity and overweight, there has been an increase in the prevalence of type 2 diabetes (84, 85). This disease was for several years considered a disease of adulthood but nowadays it occurs frequently in adolescents with BMI>30 kg/m^2 (2). NHANES III found that in the U.S. the prevalence of type 2 diabetes in adolescents was more than the double than type 1.

Type 2 diabetes ranges 90-95% of those with diabetes. This form of diabetes comprises individuals who have insulin resistance and usually have relative insulin deficiency. There are probably many different causes of this form of diabetes, most diabetic patients are obese or those who aren't obese by traditional weight criteria have an increased percentage of body fat distributed predominantly in the abdominal region. Obesity itself causes some degree of insulin resistance (86). Many overweight children also have elevated insulin levels indicating an increase in insulin resistance (87). In obese children insulin resistance and impaired insulin secretion contribute to the increase in glucose levels (88, 89).

Insulin is considered the central regulator of glucose and lipid balance. Insulin decreases blood glucose concentrations by reducing hepatic gluconeogenesis and glycogenolysis and by enhancing glucose uptake into striated muscles and adipocytes. Insulin also plays a role in the lipid metabolism enhancing triglyceride synthesis in liver and adipose tissues, increases the breakdown of circulating lipoproteins by stimulating lipoprotein lipase activity in adipose tissues, and suppresses lipolysys both in adipose tissues and muscles (90, 91).

If an adolescent has an increased insulin resistance, it can lead to increased hepatic synthesis of very-low-density lipoprotein, resistance of the action of insulin on lipoprotein lipase peripheral tissues, enhanced cholesterol synthesis, increased high density lipoprotein degradation, increased sympathetic activity, proliferation of vascular smooth muscular cells, and decreased reduction of plaque (2).

Also, we know from adults that approximately 30% of patients with pre diabetes (Impaired Fasting Glucose or Impaired Glucose Tolerance) will convert to type 2 diabetes mellitus within 5 years (92). Besides, children with pre diabetes have an increased risk for developing cardiovascular diseases before progressing to diabetes mellitus (93, 94).

Cardiovascular diseases are a major cause of death in the U.S. and are increasing worldwide (2). In parallel with the increase of metabolic syndrome and obesity and overweight, there has been an increase in the prevalence of type 2 diabetes (84, 85).

Data from the Bogalusa Heart Study proven that when insulin concentration are increased in childhood they tend to remain elevated in adulthood, and these adults tend to have increased rates of obesity, hypertension and dyslipdemia (95).

Most of the consequences of overweight in adolescence happen only some years late. On the other hand, obesity is the single most obvious risk factor for type 2 diabetes (88) and insulin resistance could be the trigger for the development of metabolic syndrome, their components or most of the cardiovascular diseases related with overweight. Glucose and their derivate indices that allow us to an indirect measure of insulin resistance could be used as surrogates of an increased risk of cardiovascular disease later in life.

AIMS

This research aimed to study the anthropometric measures that can contribute to the evaluation of overweight and obesity, and the role of these measures identifying adolescents with alterations on the glucose metabolism through the following specific objectives:

- To evaluate the ability of different body fat measures to identify overweight and obesity in 13-year-old adolescents and to identify the best cut-offs of these measures.
- We intend to evaluate the ability of different adiposity measures to identify 13 year old adolescents with high values of glucose, insulin and HOMA.

REFERENCES

1. Frota, Arlinda Chaves. Direcção Geral de Saúde. Web site da Direcção Geral de Saúde. [Online] 2007. [Citação: 12 de 09 de 2009.] http://www.dgs.pt.
2. Daniels SR, Arnett DK, Eckel RH, Gidding SS, Hayman LL, Kumanyika S, et al. Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. Circulation. 2005 Apr 19;111(15):1999-2012.
3. Seidell JC. Obesity: a growing problem. Acta Paediatr Suppl. 1999 Feb;88(428):46-50.
4. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. JAMA. 2006 Apr 5;295(13):1549-55
5. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. Int J Pediatr Obes. 2006;1(1):11-25.
6. World Health Organization. Europe. Prevalence of excess body weight and obesity in children and adolescents. Copenhagen 2007.
7. Lissau I, Overpeck MD, Ruan WJ, Due P, Holstein BE, Hediger ML. Body mass index and overweight in adolescents in 13 European countries, Israel, and the United States. Arch Pediatr Adolesc Med. 2004 Jan;158(1):27-33.
8. World Health Organization. Inequalities in Young People's Health: Health Behaviour in School-aged Children (HBSC) international report from the 2005/2006 survey. World Health Organization. *Health Policy for Children and Adolescents*, No. 5. WHO Regional Office for Europe: Copenhagen, 2008.
9. Padez C, Fernandes T, Mourao I, Moreira P, Rosado V. Prevalence of overweight and obesity in 7-9-year-old Portuguese children: trends in body mass index from 1970-2002. *Am J Hum Biol.* Nov-Dec 2004;16(6):670-678
10. Rosa ER. *Estudos sobre o desenvolvimento da criança*. Lisboa: Ministério da Educação; 1983.
11. Fragoso MI. Medidas antropométricas. *Normas antropométricas da população infantil de Lisboa.* Vol 2. Lisboa: Câmara Municipal. Pelouro da Educação; 1992.
12. Yngve A, De Bourdeaudhuij I, Wolf A, et al. Differences in prevalence of overweight and stunting in 11-year olds across Europe: The Pro Children Study. *Eur J Public Health.* Apr 2008;18(2):126-130.
13. Ramos E, Barros H. Family and school determinants of overweight in 13-year-old Portuguese adolescents. *Acta Paediatr.* Feb 2007;96(2):281-286.

14. Miranda A, Ramos E, Araújo J, Alarcão V, Lopes C, Galvão-Teles A. Regional differences in the prevalence of overweight and obesity in Portuguese children (2-5years) and adolescents (11-15 years). Public Health Nutr. 2010;13(9A):188.
15. Freedman DS, Sherry B. The validity of BMI as an indicator of body fatness and risk among children. Pediatrics. 2009 Sep;124 Suppl 1:S23-34.
16. Marrodán Serrano MD, Mesa Santurino MS, Alba Díaz JA, Ambrosio Soblechero B, Barrio Caballero PA, Drak Hernández L, et al. Diagnosis de la Obesidad: Actualización de Criterios y su Validez Clínica y Poblacional. An Pediatr (Barc). 2006 Jul;65(1):5-14.
17. Turconi G, Guarcello M, Maccarini L, Bazzano R, Zaccardo A, Roggi C. BMI values and other anthropometric and functional measurements as predictors of obesity in a selected group of adolescents. Eur J Nutr. 2006 Mar;45(3):136-43.
18. Guo SS, Wu W, Chumlea WC, Roche AF. Predicting overweight and obesity in adulthood from body mass index values in childhood and adolescence. Am J Clin Nutr. 2002 Sep;76(3):653-8.
19. Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. Pediatrics. 2007 Dec;120 Suppl 4:S193-228.
20. Berenson GS. Health consequences of obesity. Pediatr Blood Cancer. 2012 Jan;58(1):117-21.
21. Pelone F, Specchia ML, Veneziano MA, Capizzi S, Bucci S, Mancuso A, et al. Economic impact of childhood obesity on health systems: a systematic review. Obes Rev. 2011 Dec 29.
22. Saha AK, Sarkar N, Chatterjee T. Health consequences of childhood obesity. Indian J Pediatr. 2011 Nov;78(11):1349-55.
23. Must A, Strauss RS. Risks and consequences of childhood and adolescent obesity. Int J Obes Relat Metab Disord. 1999 Mar;23 Suppl 2:S2-11.
24. Dietz WH. Critical periods in childhood for the development of obesity. Am J Clin Nutr. 1994 May;59(5):955-9
25. Ben-Shlomo Y, Kuh D. A life course approach to chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives. Int J Epidemiol. 2002 Apr;31(2):285-93
26. Barker DJ. The fetal origins of diseases of old age. Eur J Clin Nutr. 1992 Oct;46 Suppl 3:S3-9.

27. Cameron N, Demerath EW. Critical periods in human growth and their relationship to diseases of aging. Am J Phys Anthropol. 2002;Suppl 35:159-84.
28. Ong KK, Ahmed ML, Emmett PM, Preece MA, Dunger DB. Association between postnatal catch-up growth and obesity in childhood: prospective cohort study. BMJ. 2000 Apr 8;320(7240):967-71.
29. Dulloo AG, Jacquet J, Seydoux J, Montani JP. The thrifty 'catch-up fat' phenotype: its impact on insulin sensitivity during growth trajectories to obesity and metabolic syndrome. Int J Obes (Lond). 2006 Dec e 4:S23-35., 30 Suppl.
30. Rolland-Cachera MF, Deheeger M, Bellisle F, Sempé M, Guilloud-Bataille M, Patois E. Adiposity rebound in children: a simple indicator for predicting obesity. Am J Clin Nutr. 1984 Jan;39(1):129-35.
31. Naumova EN, Must A, Laird NM. Tutorial in Biostatistics: Evaluating the impact of 'critical periods' in longitudinal studies of growth using piecewise mixed effects models. Int J Epidemiol. 2001 Dec;30(6):1332-41.
32. Suliga E. Visceral adipose tissue in children and adolescents: a review. Nutr Res Rev. 2009 Dec;22(2):137-47.
33. Hammer LD, Wilson DM, Litt IF, Killen JD, Hayward C, Miner B, Vosti C, Taylor CB. Impact of pubertal development on body fat distribution among white, Hispanic, and Asian female adolescents. J Pediatr. 1991 Jun;118(6):975-80.
34. Wells JC. Sexual dimorphism of body composition. Best Pract Res Clin Endocrinol Metab. 2007 Sep;21(3):415-30.
35. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000 May 6;320(7244):1240-3.
36. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC Growth Charts for the United States: methods and development. Vital Health Stat 11. 2002 May;(246):1-190.
37. Dietitians of Canada, Canadian Paediatric Society, The College of Family Physicians of Canada, A health professional's guide for using the new WHO growth charts. Paediatr Child Health. 2010 Feb;15(2):84-98.
38. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007 Sep;85(9):660-7.

39. WHO Child Growth Standards based on length/height, weight and age. Acta Paediatr Suppl. Apr 2006 e 450:76-85.

40. Feldman R, Sender AJ, Siegelaub AB. Difference in diabetic and non diabetic fat distribution patterns by skinfold measurements. Diabetes. 1969 Jul;18(7):478-86.

41. Wei M, Gaskill SP, Haffner SM, Stern MP. Waist circumference as the best predictor of noninsulin dependent diabetes mellitus (NIDDM) compared to body mass index, waist/hip ratio and other anthropometric measurements in Mexican Americans--a 7-year prospective study. Obes Res. 1997 Jan;5(1):16-23.

42. Albrink MJ, Meigs JW. Interrelationship between skinfold thickness, serum lipids and blood sugar in normal men. Am J Clin Nutr. 1964 Nov;15:255-61.

43. Kissebah AH, Vydelingum N, Murray R, Evans DJ, Hartz AJ, Kalkhoff RK, et al. Relation of body fat distribution to metabolic complications of obesity. J Clin Endocrinol Metab. 1982 Feb;54(2):254-60.

44. Zhu S, Wang Z, Heshka S, Heo M, Faith MS, Heymsfield SB. Waist circumference and obesity-associated risk factors among whites in the third National Health and Nutrition Examination Survey: clinical action thresholds. Am J Clin Nutr. 2002 Oct;76(4):743-9.

45. Ferreira I, Snijder MB, Twisk JW, van Mechelen W, Kemper HC, Seidell JC. Central fat mass versus peripheral fat and lean mass: opposite (adverse versus favorable) associations with arterial stiffness? The Amsterdam Growth and Health Longitudinal Study. J Clin Endocrinol Metab. 2004 Jun;89(6):2632-9.

46. Grundy SM. Metabolic complications of obesity. Endocrine. 2000 Oct;13(2):155-65.

47. Ferreira I, Twisk JW, van Mechelen W, Kemper HC, Seidell JC, Stehouwer CD. Current and adolescent body fatness and fat distribution: relationships with carotid intima-media thickness and large artery stiffness at the age of 36 years. J Hypertens. 2004 Jan;22(1):145-55.

48. Freedland ES. Role of a critical visceral adipose tissue threshold (CVATT) in metabolic syndrome: implications for controlling dietary carbohydrates: a review. Nutr Metab (Lond). 2004 Nov 5;1(1):12.

49. Benfield LL, Fox KR, Peters DM, Blake H, Rogers I, Grant C, et al. Magnetic resonance imaging of abdominal adiposity in a large cohort of British children. Int J Obes (Lond). 2008 Jan;32(1):91-9. Epub 2007 Nov 27.

50. Vague J. The degree of masculine differentiation of obesities: a factor determining predisposition to diabetes, atherosclerosis, gout, and uric calculous disease. 1956. Nutrition. 1999 Jan;15(1):89-90; discussion 91.

51. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0·5 could be a suitable global boundary value. Nutr Res Rev. 2010 Dec;23(2):247-69. Epub 2010 Sep 7.

52. Moreira C, Santos R, Vale S, Santos PC, Abreu S, Marques AI, et al. Ability of different measures of adiposity to identify high metabolik risk in adolescents. J Obes. 2011;2011:578106. Epub 2011 Jul 11.

53. Maffeis C, Pietrobelli A, Grezzani A, Provera S, Tatò L. Waist circumference and cardiovascular risk factors in prepubertal children. Obes Res. 2001 Mar;9(3):179-87.

54. Freedman DS, Serdula MK, Srinivasan SR, Berenson GS. Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: the Bogalusa Heart Study. Am J Clin Nutr. 1999 Feb;69(2):308-17.

55. Fox CS, Massaro JM, Hoffmann U, Pou KM, Maurovich-Horvat P, Liu CY, et al Abdominal visceral and subcutaneous adipose tissue compartments: association with metabolic risk factors in the Framingham Heart Study.Circulation. 2007 Jul 3;116(1):39-48.

56. Wajchenberg BL. Subcutaneous and visceral adipose tissue: their relation to the metabolic syndrome. Endocr Rev. 2000 Dec;21(6):697-738.

57. Bouchard C. BMI, fat mass, abdominal adiposity and visceral fat: where is the 'beef'? Int J Obes (Lond). 2007 Oct;31(10):1552-3. Epub 2007 Jun 5.

58. Fox KR, Peters DM, Sharpe P, Bell M. Assessment of abdominal fat development in young adolescents using magnetic resonance imaging. Int J Obes Relat Metab Disord. 2000 Dec;24(12):1653-9.

59. Caprio S, Hyman LD, McCarthy S, Lange R, Bronson M, Tamborlane WV. Fat distribution and cardiovascular risk factors in obese adolescent girls: importance of the intraabdominal fat depot. Am J Clin Nutr. 1996 Jul;64(1):12-7.

60. Syme C, Abrahamowicz M, Leonard GT, Perron M, Pitiot A, Qiu X, et al. Intraabdominal adiposity and individual components of the metabolic syndrome in

adolescence: sex differences and underlying mechanisms. Arch Pediatr Adolesc Med. 2008 May;162(5):453-61.

61. Ibrahim MM. Subcutaneous and visceral adipose tissue: structural and functional differences. Obes Rev. 2010 Jan;11(1):11-8.

62. Aucouturier J, Duché P, Timmons BW. Metabolic flexibility and obesity in children and youth. Obes Rev. 2011 May;12(5):e44-53.

63. Oliveira A, Lopes C, Severo M, Rodríguez-Artalejo F, Barros H. Body fat distribution and C-reactive protein--a principal component analysis. Nutr Metab Cardiovasc Dis. 2011 May;21(5):347-54.

64. Kim JA, Park HS. White blood cell count and abdominal fat distribution in female obese adolescents. Metabolism. 2008 Oct;57(10):1375-9.

65. Siri WE. Body composition from fluid spaces and density: analysis of methods. 1961. Nutrition. 1993 Sep-Oct;9(5):480-91; discussion 480, 492.

66. Rodríguez G, Moreno LA, Blay MG, Blay VA, Fleta J, Sarría A, Bueno M. Body fat measurement in adolescents: comparison of skinfold thickness equations with dual-energy X-ray absorptiometry. Eur J Clin Nutr. 2005 Oct;59(10):1158-66.

67. Sarría A, Moreno LA, García-Llop LA, Fleta J, Morellón MP, Bueno M. Body mass index, triceps skinfold and waist circumference in screening for adiposity in male children and adolescents. Acta Paediatr. 2001 Apr;90(4):387-92.

68. Lindsay RS, Hanson RL, Roumain J, Ravussin E, Knowler WC, Tataranni PA. Body mass index as a measure of adiposity in children and adolescents: relationship to adiposity by dual energy x-ray absorptiometry and to cardiovascular risk factors. J Clin Endocrinol Metab. 2001 Sep;86(9):4061-7.

69. Wang J, Thornton JC, Kolesnik S, Pierson RN Jr. Anthropometry in body composition. An overview. Ann N Y Acad Sci. 2000 May;904:317-26.

70. Kettaneh A, Heude B, Lommez A, Borys JM, Ducimetière P, Charles MA. Reliability of bioimpedance analysis compared with other adiposity measurements in children: the FLVS II Study. Diabetes Metab. 2005 Dec;31(6):534-41

71. Himes JH. Challenges of accurately measuring and using BMI and other indicators of obesity in children. Pediatrics. 2009 Sep;124 Suppl 1:S3-22.

72. Gibson RS. Principles of nutricional Assessment.2nd ed. New York: Oxford University Press; 2005.

73. Lohman TG, Roche AF, Martorell R. Anthropometrics standardization reference manual. Champaign: Human Kinetics, 1988

74. Sardinha LB, Going SB, Teixeira PJ, Lohman TG. Receiver operating characteristic analysis of body mass index, triceps skinfold thickness, and arm girth for obesity screening in children and adolescents. Am J Clin Nutr. 1999 Dec;70(6):1090-5.

75. Fernández JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. J Pediatr. 2004 Oct;145(4):439-44.

76. Brambilla P, Bedogni G, Moreno LA, Goran MI, Gutin B, Fox KR, et al. Crossvalidation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcutaneous adipose tissue in children. Int J Obes (Lond). 2006 Jan;30(1):23-30.

77. Freedman DS, Kahn HS, Mei Z, Grummer-Strawn LM, Dietz WH, Srinivasan SR, et al. Relation of body mass index and waist-to-height ratio to cardiovascular disease risk factors in children and adolescents: the Bogalusa Heart Study. Am J Clin Nutr. 2007 Jul;86(1):33-40.

78. Singh AS, Chin A Paw MJ, Brug J, van Mechelen W. Dutch obesity intervention in teenagers: effectiveness of a school-based program on body composition and behavior. Arch Pediatr Adolesc Med. 2009 Apr;163(4):309-17.

79. Power C, Lake JK, Cole TJ. Measurement and long-term health risks of child and adolescent fatness. Int J Obes Relat Metab Disord. 1997 Jul;21(7):507-26.

80. Ramos E, Barros H. Prevalência de Hipertensão Arterial em Adolescentes de13 Anos da Cidade do Porto. Rev Port Cardiol 2005;24 (9) :1075-1087.

81. Johnson WD, Kroon JJ, Greenway FL, Bouchard C, Ryan D, Katzmarzyk PT. Prevalence of risk factors for metabolic syndrome in adolescents: National Health and Nutrition Examination Survey (NHANES), 2001-2006. Arch Pediatr Adolesc Med. 2009 Apr;163(4):371-7.

82. Cook S, Weitzman M, Auinger P, Nguyen M, Dietz WH. Prevalence of a metabolic syndrome phenotype in adolescents: findings from the third National Health and Nutrition Examination Survey, 1988-1994. Arch Pediatr Adolesc Med. 2003 Aug;157(8):821-7.

83. Goodman E, Daniels SR, Meigs JB, Dolan LM. Instability in the diagnosis of metabolic syndrome in adolescents. Circulation. 2007 May 1;115(17):2316-22.

84. Pinhas-Hamiel O, Dolan LM, Daniels SR, Standiford D, Khoury PR, Zeitler P. Increased incidence of non-insulin-dependent diabetes mellitus among adolescents. J Pediatr. 1996 May;128(5 Pt 1):608-15.

85. Gardete-Correia L, Boavida JM, Raposo JF, Mesquita AC, Fona C, Carvalho R, et al. First diabetes prevalence study in Portugal: PREVADIAB study. Diabet Med. 2010 Aug;27(8):879-81.

86. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care. 2008 Jan;31 Suppl 1:S55-60.

87. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. Pediatrics. 1999 Jun;103(6 Pt 1):1175-82.

88. Silink M. Childhood diabetes: a global perspective. Horm Res. 2002;57 Suppl 1:1-5.

89. Amed S, Daneman D, Mahmud FH, Hamilton J. Type 2 diabetes in children and adolescents. Expert Rev Cardiovasc Ther. 2010 Mar;8(3):393-406.

90. Keskin M, Kurtoglu S, Kendirci M, Atabek ME, Yazici C. Homeostasis model assessment is more reliable than the fasting glucose/insulin ratio and quantitative insulin sensitivity check index for assessing insulin resistance among obese children and adolescents. Pediatrics. 2005 Apr;115(4):e500-3.

91. Galli-Tsinopoulou A, Karamouzis M, Nousia-Arvanitakis S. Insulin resistance and hyperinsulinemia in prepubertal obese children. J Pediatr Endocrinol Metab. 2003 Apr-May;16(4):555-60.

92. Rasmussen SS, Glumer C, Sandbaek A, Lauritzen T, Borch-Johnsen K. Determinants of progression from impaired fasting glucose and impaired glucose tolerance to diabetes in a high-risk screened population: 3 year followup in the ADDITION study, Denmark. Diabetologia. 2008 Feb;51(2):249-57.

93. Reinehr T, Kiess W, de Sousa G, Stoffel-Wagner B, Wunsch R. Intima media thickness in childhood obesity: relations to inflammatory marker, glucose metabolism, and blood pressure. Metabolism. 2006 Jan;55(1):113-8

94. Definition and diagnosis of diabetes mellitus and intermediate hyperglycemia: report of a WHO/IDF consultation. Geneva: World Health Organization2006

95. Bao W, Srinivasan SR, Berenson GS, Persistent elevation of plasma insulin levels is associated with increased cardiovascular risk in children and young adults. The Bogalusa Heart Study. Circulation. 1996 Jan 1;93(1):54-9.

CHAPTERS

CHAPTER 1

Body fat measurements: evaluating obesity and overweight in adolescents

ABSTRACT

Aims: We aimed to evaluate the ability of different body fat measures to identify overweight and obesity in 13-year-old adolescents and to identify the best cut-offs of these measures.

Design: Cross-sectional study in 13-year-old adolescents registered at public and private schools of Porto, Portugal (EPITEEN Study)

Participants and methods: We have analyzed 1950 adolescents (51.5% of girls), we measured height, weight, waist circumference, tricipital and bicipital skinfold thickness. We also estimated body fat percentage using Tanita®. All anthropometric measurements were obtained with the subject standing, in light indoor clothes and no shoes, according to international guidelines. To compare means we used the Wilcoxon-Mann-Whitney and to examine relations between the different anthropometric measurements and BMI we used Spearman correlation coefficient. The diagnostic value of the different measures of adiposity was through the receiver-operating characteristic (ROC) curve analyses. The area under the curve (AUC) is also presented.

Results: In our sample the prevalence of overweight (BMI ≥85th) was 11.9% in boys and 12.4% among girls. Body mass index was positively and significantly correlated with all anthropometric measures, in both genders. In boys the stronger association was found with waist circumference, both in adolescents with BMI <85th and ≥85th. In girls, the stronger association was found with body fat percentage for those with BMI<85th [0.79(95% CI: 0.77; 0.82)] and with waist circumference among those with BMI≥85th [0.71(95% CI: 0.59; 0.80)]. Waist circumference, using the 75th percentile as cut-off, was the anthropometric measure that better identified the adolescents with BMI ≥85th percentile. Sensitivity was 100% in boys and 97.6% (95% CI: 94.9-100) in girls; specificity was 85.5% (95% CI: 83.1-87.9) and 85.8% (95% CI: 83.5-88.1). When the waist to height ratio was used those values were 86.7% (95% CI: 80.5-93.0); 86.3% (95% CI: 80.2-92.3) for sensibility, and 92.9% (95% CI: 91.2-94.7); 94.8% (95% CI: 93.3-96.2) for specificity.

Conclusions: Beyond BMI, waist circumference seems to be a sensitive and specific tool for the detection of overweight in adolescents. Additionally, the use of the waist to height ratio may improve the specificity of this measure. In contrast, skinfolds measurements have presented a very low accuracy to identify overweight in this group.

INTRODUCTION

The World Health Organization (WHO) considers obesity as a major public health challenge for the XXI century. In Europe, the prevalence of overweight and obesity in adults has tripled in the last two decades (1).This trend is also observed in children and adolescents, being more evident in the countries of southern Europe with a higher prevalence of overweight compared with other countries in Europe (2, 3). So, there is a need to monitor and determine obesity risk status among children and adolescents, in order to plan measures of care and prevention (19).

However, the inexistence of an international consensus about how to measure overweight and obesity makes difficult the comparison of cross-sectional prevalence data, as well the clear identification of its trends (19).

The Body Mass Index (BMI), which relates the weight in kilograms with height in meters using the formula (BMI = weight / height^2), is a measure commonly used to identify the overweight and obese subjects. However, this measure does not take into account the differences in weight regarding muscle mass or fat mass (4).

There are other methods to access obesity and overweight that are based on a more accurate measure of body composition. The underwater weights, the ultrasound and the X-ray absorptiometry dual radiation (DEXA) are considered reference methods because of their precision (5, 6). However, these methods are expensive and difficult to use in a large sample (5, 7).

Estimations based on measurements of circumferences, skinfold thickness and bioimpedance are less expensive, non-invasive, relatively easy to apply in field studies and allow taking into account the different components of the body which provide an estimate of the total body fat (4, 8-10).

Additionally, visceral fat and subcutaneous fat have morphological and functional differences (11). It is accepted that obesity consequences, namely cardiovascular diseases, can be determined both by the amount of fat and its distribution (12). The measurement of skinfold thickness allows to estimate not only total fat but also subcutaneous fat, however, they require a trained evaluator for the measurement to be reliable (4, 9).

Despite the difficulty in identifying the best measure of adiposity to be similar to various age groups, among children and adolescents the problem of the measurement of the overweight and obesity is greater since no consensual criteria has been defined. Though BMI is only an indirect measure of fatness, the International Obesity Task

Force and the WHO recommended it to classify overweight in children and adolescents (13, 14). On the other hand, this lack of definition increased the difficulty to determine the relationship between BMI (the more consensual criteria) and other measures of adiposity that may allow studying the effect of body fat distribution on health of children and adolescents.

Thus, we aimed to evaluate the ability of different body fat measures (height, weight, waist circumference, tricipital and bicipital skinfold thickness and body fat percentage) to identify overweight in 13-year-old adolescents and to identify the best cut-offs of these measures.

Participants and methods

During 2003/2004 school year, participants were selected as part of the assembling procedure of the Epiteen Cohort (15), which intends to follow adolescents born in 1990 and registered at every public and private schools of Porto, a large urban center in the north-west of Portugal. We identified 2787 eligible adolescents (2126 in public and 661 in private schools). Forty-four children (1.6%) could not be reached (missing classes during the study period), 584 (20.9%) were considered refusals since no signed informed consent form was returned, and 2160 (1651 public and 509 private school students) agreed to participate and provided information at least for part of the planned assessment. This resulted in a 77.5% overall participation proportion, similar in public (77.7%) and private schools (77.0%, p=0.709).

From the initial sample of 2160 adolescents, we exclude 210 adolescents with missing information in any of the anthropometric measures analyzed. The final sample included 1950 adolescents, with a girl's proportion of 51.5%.

The Ethical Committee of the Hospital of São João, Porto, approved the study. Parents and children received written information explaining the purpose and the design of the study. Additionally, the study steps were described in each school during special meetings arranged according to parents' convenience. Written informed consent was obtained both from parents and children.

The evaluation comprised two self-administered questionnaires (one completed at home, another at school), comprising information on demographic, social, and behavioral characteristics and a physical examination performed at school, by a team of experienced nurses, nutritionists and physicians.

We considered the practice of sport activities when the participant was engaged in some physical leisure time activity performed on a repeated basis, spending at least 30 minutes a week and not included in the school curriculum. The parental education level was measured as the number of successfully completed years of formal schooling and we considered the parent with the highest education level.

Anthropometric measures and related indices

All measurements were obtained with the subject standing, in light indoor clothes and no shoes.

A digital scale -(Tanita TBF-300) was used to measure the weight (in kilograms, to the nearest tenth) and the body fat percentage. The height was measured (in centimetres, to the nearest tenth) using a portable stadiometer.

Skinfolds Thickness

The skinfolds thickness was measured with a Harpenden calliper with a constant pressure of 10 g/mm^2. We measured a vertical pinch at the level of the mid-point between acromial process and proximal end of the radius bone, on the posterior surface of the arm for the tricipital and on the anterior surface of arm for the bicipital skinfold thickness (8).

Each skinfold was measured in the no dominant side of the body. We registered three measurements for each skinfold and considered the final result as the mean of them.

For the analysis based on the literature criterion, we classified adolescents according to the percentiles described for Spanish and Portuguese population (6, 10), considering as overweight those adolescents with values of each skinfold were $\geq 75^{th}$ percentile (6,10).

Waist Circumference

The circumferences were measured in centimetres (to the nearest tenth) with a flexible and non-distensible tape, avoiding exertion of pressure on the tissues and with the subject standing. The waist circumference was measured midway between the lower limit of the rib cage and the iliac crest, at the end of gentle expiration. The hip circumference was the maximal circumference over the femoral trochanters. The arm circumference was measured in the mid-point between acromial process and proximal end of the radius bone (17).

For the analysis based on the literature criterion, we classified adolescents according to the percentile described by other authors considering overweight adolescents with values of waist circumference were ≥75^{th} percentile (16).

<u>Body Mass Index (BMI)</u>

Using the measured weight and height, BMI was calculated according to the formula (BMI = weight/height^2). Then, according to the age- and sex-specific body mass index reference percentiles developed by the United States Centres for Disease Control and Prevention (13) participants were considered pre-obese if BMI was at or above 85^{th} and below the 95^{th} percentile, and obese if BMI was at or above the 95^{th} percentile (14).

In the article and for the statistical analysis we considered participants with BMI at or above 85^{th} as overweight, assembling the two percentiles (≥85^{th} and ≥ 95^{th}), because the prevalence of obese participants (BMI ≥ 95^{th} percentile) was low.

<u>Waist to height ratio</u>

Waist to height ratio (WHtR) was calculated using the formula WHtR = waist/height, and based on the literature the 0.5 was used cut-off point for classifying adolescents (12).

Statistical Analysis

Statistical analysis was performed using SPSS®, version 17.0 (SPSS Inc, Chicago, Illinois).. To compare averages we used the Wilcoxon-Mann-Whitney. A significant level of 0.05 was assumed.

To examine relations between each anthropometric measurements and BMI we used de Spearman correlation coefficient.

Receiver-operating characteristic (ROC) curve analyses were used to analyse the potential diagnostic accuracy of the different measures of adiposity to discriminate between normal weight and overweight assuming 85^{th} percentile as cut-off.

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and positive and negative Likelihood Ratio (PLR and NLR) of the different cut-offs were calculated, , both with the cut-off referred in literature and regarding the cut-off identify in our sample, that maximize sensibility and specificity.

The area under the curve (AUC) is also presented. The AUC represents the ability of the anthropometric measure tested to correctly classify the adolescents with overweight (18).

RESULTS

In our sample the prevalence of adolescents that reported practice sports was low, namely in girls. The prevalence of overweight was 11.9% in boys and 12.4% among girls. Except the waist to height ratio, all the other measures of body fat presented higher values among girls (*Table1*).

Table 2 shows the correlation coefficients between biceps and triceps skinfolds, body fat percentage, waist to height ratio, waist circumference and BMI, among normal or underweight adolescents (BMI<85^{th}) percentile and among overweight adolescents (BMI≥85^{th} percentile). Body mass index was positively and significantly correlated with all anthropometric measures, in boys and girls. In boys the stronger association was found with waist circumference, both in adolescents with BMI <85^{th} [ρ=0.83 (95%CI: 0.81; 0.85)] and those with BMI ≥85^{th} [ρ=0.76 (95%CI: 0.68; 0.83)]. In girls, the stronger association was found with body fat percentage for those with BMI <85^{th} [ρ=0.793(95%CI: 0.77; 0.82)] and with waist circumference among those with BMI≥85^{th} [ρ=0.711(95%CI: 0.59; 0.80)]. The associations with bicipital skinfolds were the weakest for boys and girls in both BMI classes.

In *Table 3* we present sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and positive and negative likelihood ratio (PLR and NLR) of each anthropometric measure considering the cut-offs described in the literature. Considering those cut-offs, the anthropometric measure that better identifies adolescents with BMI ≥85^{th} percentile was the waist circumference, and, if combined with waist to height ratio the specificity is increased The anthropometric measures that presented the worst ability to identify overweight adolescents were the bicipital and tricipital skinfolds.

We also identified the cut-off that presented the best ability to identify overweight adolescents in our sample (table 3). In general, the cut-offs identified were similar to those reported in the literature, although the difference was higher in boys than in girls. For all adiposity measures the cut-offs based on the literature presented a higher AUC than those based in our specific cut-offs.

DISCUSSION

Our data showed that waist circumference was a sensitive and specific tool for the detection of overweight in adolescents. Additionally, the specificity of this measure may be improved by the use of the waist to height ratio. In contrast, skinfolds measurements presented a very low accuracy to identify overweight in this age group.

BMI is the most practical and inexpensive tool to access overweight and obesity(19), it continues to be used in studies with large samples, like ours, because it is easy to use and it has a low cost (6, 20). Although some authors report that its accuracy in adolescents varies with the amount of fat mass (9), in our study BMI was also used as a "*gold standard*" measure to define overweight and obesity. We know that this can be considered a disadvantage because of the limitations of using BMI. However in children and adolescents it can be an excellent indicator of overweight and obesity that is sufficient for most clinical, and screening purposes (21).

Similar results regarding the use of waist circumference has been mentioned by others authors (6, 21, 22). Although the evaluation of waist circumference may be influenced by spinal curvature and posture and the amount of abdominal musculature, this anthropometric measure seems to have a similar performance to BMI to access overweight and obese adolescents (6) and it is also inexpensive and easy to use. Additionally, since BMI does not distinguish different fat distribution and cannnot distinguish between fat mass, muscle mass an skeletal mass(9, 12) the use of waist circumference or waist to height ratio can complement the information adding information regarding body fat distribution (21).

On the other hand, the bicipital and tricipital skinfolds presented a very low accuracy to identify overweight in this group. This result is in accordance with previous statements supporting that once BMI is assessed, skinfold thickness brings no relevant information to identify those with the higher percentage of body fat (4, 23). One other disadvantage of the bicipital and tricipital skinfolds is that they require a trained evaluator to be reliable (6, 8, 9). However, skinfolds may be useful to evaluate subcutaneous fat if the use of other more accurate measure, like DEXA, is not available (10).

An interesting data from our results is that for all adiposity measures the cut-offs based on the literature presented a higher AUC than those based in our specific cut-offs, supporting the use of the same cut-offs in different populations, allowing investigators to compare data from different cross-sectional prevalence studies.

Our study has as strengths the large sample size and its population-based nature. Since in Portugal at this age the school is compulsory, the use of schools as sample base allow us to believe in the representativeness of the sample. Also the measurements were done by a team of trained evaluators that allowed minimizing errors.

The homogeneity of our sample regarding age could be considered a limitation because the restriction on extrapolations to other ages. This is also strength since during adolescence a large set of changes on body composition happens (24, 25) that could modify the ability of different measures to identify adiposity. Additionally, to take into account that variability, a very large sample would be necessary.

It is known that the excess of fat in childhood brings a greater risk for adult disease without mentioning the impaired health during childhood (19). With this study we expect to bring a contribution to the standardization of cut-off points that help to identify overweight in adolescents, namely to the development of future investigations that aimed to evaluate the role of different types or distribution of body fat.

REFERENCES

1. Doak CM, Wijnhoven TM, Schokker DF, Visscher TL, Seidell JC. Age standardization in mapping adult overweight and obesity trends in the WHO European Region. Obes Rev. 2011 Nov 7.
2. Janssen I, Katzmarzyk PT, Boyce WF, Vereecken C, Mulvihill C, Roberts C, et al. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relantionships with physical activity and dietary paterns. Obes Rev 2005. May; 6(2): 123-32.
3. Lobstein T, Frelut ML. Prevalence of overweight among children in Europe. Obes Rev. 2003 Nov;4 (4):195-200
4. Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. Pediatrics. 2007 Dec;120 Suppl 4:S193-228.
5. Rodríguez G, Moreno LA, Blay MG, Blay VA, Fleta J, Sarría A, et al. Body fat measurement in adolescents:comparison of skinfold thickness equations with dual x- ray absorptiometry. Eur J Clin Nutr. 2005 Oct;59(10):1158-66.
6. Sarría A, Moreno LA, García-Llop LA, Fleta J, Morellón MP, Bueno M. Body mass index, triceps skinfold and waist circumference in screening for adiposity in male children and adolescents. Acta Paediatr. 2001 Apr;90(4):387-9
7. Lindsay RS, Hanson RL, Roumain J, Ravussin E, Knowler WC, Tataranni PA.Body mass index as a measure of adiposity in children and adolescents: relationship to adiposity by dual energy x-ray absorptiometry and to cardiovascular risk factors. J Clin Endocrinol Metab. 2001 Sep;86(9):4061-7.
8. Gibson RS. Principles of Nutricional Assessment.2nd ed. New York: Oxford University Press; 2005.
9. Freedman DS, Sherry B. The validity of BMI as an indicator of body fatness and risk among children. Pediatrics. 2009 Sep;124 Suppl 1:S23-34
10. Sardinha LB, Going SB, Teixeira PJ, Lohman TG. Receiver operating characteristic analysis of body mass index, triceps skinfold thickness and arm girth for obesity screening in children and adolescents. Am J Clin Nutr. 1999 Dec;70(6):1090-5.
11. Suliga E. Visceral adipose tissue in children and adolescents: a review. Nutr Res Rev. 2009 Dec;22 (2):137-47.

12. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutr Res Rev. 2010 Dec;23(2):247-69.

13. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC growth charts for the United States: methods and development. Vital Health Stat 11. 2002 May; (246): 1-190.

14. Daniels SR, Arnett DK, Eckel RH, Gidding SS, Hayman LL, Kumanyika S, et al. Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. Circulation. 2005 Apr 19;111 (15): 1999-2012.

15. Ramos E, Barros H. Family and school determinants of overweight in adolescents. Acta Paediatr. 2007 Feb; 96(2):281-6.

16. Moreira C, Santos R, Vale S, Santos PC, Abreu S, Marques AI, et al. Ability of different measures of adiposity to identify high metabolik risk in adolescents. J Obes. 2011;2011:578106.

17. World Health Organization. Measuring Obesity: Classification and Description of Anthropometric Data. Report on a WHO Consultation on the Epidemiology of Obesity. Copenhagen, Denmark: WHO Regional Office for Europe, Nutrition Unit; 1988.

18. Hanley JA. The robustness of the”binominal" assumptions used in fitting ROC curves. Med Decis Making. 1988 Jul-Sep;8(3):197-203.

19. de Onis M, Lobstein T. Defining obesity risk status in the general childhood population:which cut-offs should we use? Int J Pediatr Obes. 2010 Dec;5(6):458-60.

20. Wang J, Thornton JC, Kolesnik S, Pierson RN Jr. Anthropometry in body composition. an overview. Ann N Y Acad Sci. 2000 May; 904:317-26.

21. Himes JH. Challenges of accurately measuring and using BMI and other indicators of obesity in children. Pediatrics. 2009 Sep; 124 Suppl 1:S3-22.

22. Moreno LA, Fleta J, Mur L, Rodríquez G, Sarría A, Bueno M. Waist circumference values in spanish children--gender related differences. Eur J Clin Nutr. 1999 Jun;53(6):429-33.

23. Rolland-Cachera MF, Bellisle F, Sempe M. The prediction in boys and girls of the weight/height index and various skinfold measurements in adults: a two-decade follow-up study. Int J Obes. 1989;13(3): 305-11

24. Singh AS, Chin A Paw MJ, Brug J, van Mechelen W. Dutch obesity intervention inteenagers: effectiveness of a school-based program on body composition and behavior, Arch Pediatr Adolesc Med. 2009 Apr;163(4):309-17

25. Marrodán Serrano MD, Mesa Santurino MS, Alba Díaz JA, Ambrosio Soblechero B, Barrio Caballero PA, Drak Hernández L, et al. Obesity screening: updated criteria and their clinical and populational validity An Pediatr (Barc). 2006 Jul;65(1):5-14

Table 1: Sample characteristics

	Boys	Girls	
	n (%)		p-value
Parents education (years)			
0 – 6	616 (34.6)	684 (37.1)	0.83
7 – 9	360 (20.3)	327 (17.7)	
10 – 12	443 (25.0)	432 (23.4)	
>12	356 (20.1)	403 (21.8)	
Missing	105	175	
Practice of sports activity			
Yes	482(61.6)	356(39.8)	**<0.001**
No	300(38.4)	538(60.2)	
Missing	164	110	
Age at menarche (years)			
8-10	-----	83(8.7)	
11-12		546(57.2)	
13-14		178(18.6)	
Not Yeat		148(15.5)	
Missing		49	
BMI (kg/m^2)			
<85th percentile	833(88.1)	880(87.6)	**0.004**
85-95th percentile	93(9.8)	100(10.0)	
≥95th percentile	20(2.1)	24(2.4)	
	Mean (standard deviation)		p-value
Biceps skinfold (mm)	6.7 (3.9)	8.2 (3.6)	**<0.001**
Triceps skinfold (mm)	11.5 (5.4)	15.1 (4.3)	**<0.001**
Waist circumference(cm)	73.1(9.4)	71.6(8.0)	**<0.001**
% Body fat	14.7 (7.3)	26.2 (7.7)	**<0.001**
Waist to height ratio	0.5 (0.1)	0.5 (0.1)	0.26

Table 2: Correlation coefficients between Biceps skinfold, Triceps skinfold, % Body fat, Waist to height ratio, Waist circumference and BMI according to BMI class

	Boys Correlation coeficient (95% IC)				
BMI(Kg/m^2)	**Biceps skinfold**	**Triceps skinfold**	**% Body fat**	**Waist to height ratio**	**Waist circumference**
<85th	0.518 [0.47;0.57]	0.643 [0.60;0.68]	0.743 [0.60;0.77]	0.723 [0.69;0.75]	0.829 [0.81;0.85]
≥85th	0.284 [0.11;0.45]	0.399 [0.23;0.54]	0.662 [0.54;0.75]	0.708 [0.60;0.79]	0.765 [0.68;0.83]
	Girls **Correlation coeficient (‘) (95% IC)**				
<85th	0.463 [0.41;0.51]	0.662 [0.62;0.70]	0.793 [0.77;0.82]	0.716 [0.68;0.75]	0.734 [0.69;0.77]
≥85th	0.136 [-0.04;0.31]	0.405 [0.25;0.54]	0.523 [0.38;0.64]	0.697 [0.59;0.78]	0.711 [0.59;0.80]

Table 3: Diagnostic value of the different measures of adiposity in detecting overweight, taking BMI as reference, according to sex

	Cut-off from the literature		*Cut-off defined in our sample*	
	Girls	**Boys**	**Girls**	**Boys**
Biceps Skinfold				
Cut-off *(mm)*	9.5(p_{75})*	8.1(p_{75})*	9.1	6.5
Sensitivity (95% CI)	70.2 (62.1-78.2)	80.5 (73.2-87.8)	67.2 (60.8-73.2)	85.7 (80.7-89.8)
Specificity (95% CI)	82.2 (79.6-84.7)	83.0 (80.5-85.5)	82.6 (79.7-85.2)	78.3 (75.1-81.3)
PPV (95% CI)	35.7 (29.6-41.7)	39.1 (32.8-45.4)	54.1 (48.2-59.9)	58.0 (52.7-63.1)
NPV (95% CI)	95.1 (93.6-96.7)	96.9 (95.6-98.2)	89.2 (86.7-91.4)	94.0 (91.8-95.8)
PLR (95% CI)	3.9 (3.3-4.7)	4.7 (4.0-5.6)	3.9 (3.2-4.6)	4.0 (3.4-4.6)
NLR (95% CI)	0.4 (0.3-0.5)	0.2 (0.2-0.3)	39.7 (32.9-47.8)	0.2(0.1-0.3)
AUC	0.843	0.892	0.831	0.883
Triceps Skinfold				
Cut-off *(mm)*	18.0(p_{75}) *	16.7(p_{75}) *	17.9	11.2
Sensitivity (95% CI)	77.4 (70.1-84.8)	86.7 (80.5-93.0)	70.6 (64.4-76.4)	89.4 (84.8-92.9)
Specificity (95% CI)	84.8 (82.4-87.1)	83.7 (81.2-6.2)	86.5 (83.8-88.8)	76.8 (73.5-80.0)
PPV (95% CI)	41.7 (35.4-48.1)	41.9 (35.6-48.2)	61.5 (55.4-67.3)	57.3 (52.2-62.3)
NPV (95% CI)	96.4 (95.1-97.7)	97.9 (96.8-98.9)	90.6 (88.2-92.6)	95.4 (93.3-97.0)
PLR (95% CI)	5.1 (4.2-6.1)	5.3 (4.5-6.3)	5.2 (4.3-6.4)	3.9 (3.3-4.4)
NLR (95% CI)	0.3 (0.2-0.4)	0.2 (0.1-0.3)	0.3 (0.3-0.4)	0.1 (0.1-0.2)
AUC	0.893	0.935	0.875	0.915
Percentage of Body Fat				
Cut-off *(%)*	31.1(p_{75}) †	18.4(p_{75}) †	30.0	15.9
Sensitivity (95% CI)	93.5 (89.2-97.9)	92.9 (88.2-97.6)	88.1 (83.2-91.9)	91.8 (87.7-94.9)
Specificity (95% CI)	85.1 (82.8-87.5)	85.0 (82.6-87.4)	86.0 (83.3-88.3)	86.3 (83.6-88.8)
PPV (95% CI)	50.0 (40.7-53.2)	45.7 (39.2-52.1)	65.7 (60.2-70.9)	70.1 (64.8-75.0)
NPV (95% CI)	98.9 (98.2-99.7)	98.9 (98.1-99.7)	95.9 (94.2-97.3)	96.8 (95.1-98.0)
PLR (95% CI)	6.3 (5.3-7.4)	6.2 (5.2-7.3)	6.3 (5.2-7.5)	6.7 (5.6-8.1)
NLR (95% CI)	0.1 (0.0-0.2)	0.1 (0.0-0.2)	0.1 (0.1-0.2)	0.1 (0.1-0.1)
AUC	0.964	0.959	0.944	0.952
Waist Circumference				
Cut-off *(cm)*	75.4(p_{75}) #	77.9(p_{75})#	72.5	75.5
Sensitivity (95% CI)	97.6 (94.9-100)	100	94.5 (90.7-97.0)	90.6 (86.2-94.0)
Specificity (95% CI)	85.8 (83.5-88.1)	85.5 (83.1-87.9)	81.5 (78.6-84.2)	90.2 (87.8-92.3)
PPV (95% CI)	49.2 (42.9-55.4)	48.3 (41.9-54.7)	61.0 (55.8-66.0)	76.3 (71.0-81.0)
NPV (95% CI)	99.6 (99.2-100)	100	98.0 (96.6-98.9)	96.5 (94.8-97.8)
PLR (95% CI)	6.9 (5.8-8.1)	6.9 (5.8-8.1)	5.1 (4.4-6.0)	9.2 (7.3-11.6)
NLR (95% CI)	0.0 (0.0-0.1)	0.00	0.1 (0.0-0.1)	0.1 (0.1-0.2)
AUC	0.978	0.981	0.951	0.962
Waist to Height ratio				
Cut-off	0.5††	0.5††	0.48	0.46
Sensitivity (95% CI)	86.3 (80.2-92.3)	86.7 (80.5-93.0)	85.5 (80.4-89.8)	89.4 (84.8-92.9)
Specificity (95% CI)	94.8 (93.3-96.2)	92.9 (91.2-94.7)	91.8 (89.6-93.6)	88.7 (86.2-91.0)
PPV (95% CI)	70.0 (62.7-77.2)	62.4 (54.8-69.9)	76.1 (70.5-81.1)	73.5 (68.1-78.4)
NPV (95% CI)	98.0 (97.1-98.9)	98.1 (97.1-99.0)	95.4 (93.6-96.8)	96.0 (94.2-97.4)
PLR (95% CI)	16.5 (12.4-22.1)	12.3 (9.5-15.9)	10.4 (8.19-13.3)	8.0 (6.4-9.8)
NLR (95% CI)	0.1 (0.1-0.2)	0.14 (0.1-0.2)	0.2 (0.1-0.2)	0.1 (0.1-0.2)
AUC	0.978	0.972	0.952	0.949

PPV- Positive predictive value; **NPV-** Negative predictive value; **PLR-** Positive likelihood ratio; **NLR**- Negative likelihood ratio; **AUC-**Area under the curve

*Sardinha LB, Going SB, Teixeira PJ, Lohman TG. Receiver operating characteristic analysis of body mass index, triceps skinfold thickness, and arm girth for obesity screening in children and adolescents. Am J Clin Nutr. 1999 Dec;70(6):1090-5.

†Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. Pediatrics. 2007 Dec;120 Suppl 4:S193-228.

Moreira C, Santos R, Vale S, Santos PC, Abreu S, Marques AI, et al. Ability of different measures of adiposity to identify high metabolik risk in adolescents. J Obes. 2011;2011:578106. Epub 2011 Jul 11.

†† Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutr Res Rev. 2010 Dec;23(2):247-69. Epub 2010 Sep 7

CHAPTER 2

Obesity and overweight: their role in blood glucose and insulin levels in adolescents

ABSTRACT

Aims: We intend to evaluate the ability of different adiposity measures to identify 13 year old adolescents with high values of glucose, insulin and HOMA.

Design: Cross–sectional study of adolescents born in 1990 and registered at every public and private schools of Porto, Portugal (EPITEEN Study).

Participants and methods: We analysed 1248 adolescents, with a girl's percentage of 51.7%, after exclusion of participants with incomplete information on anthropometric data and analytic values. All anthropometric measurements were obtained with the subject standing, in light indoor clothes and no shoes. A 12 hour overnight intravenous blood sample was taken from an antecubital vein. We used the Wilcoxon-Mann-Whitney to compare averages and to examine relations between the different anthropometric measurements and blood serum levels of insulin, glucose and HOMA we used de Spearman correlation coefficient. Receiver-operating characteristic (ROC) curve analyses were used to analyse the potential diagnostic accuracy of the different measures of adiposity to discriminate between low and high insulin, glucose and HOMA, assuming the 75th percentile as cut-off. The area under the curve (AUC) is also presented.

Results: In our sample the prevalence of overweight (BMI ≥85thpercentile) was 12.5%. In both sexes all of the anthropometric measurements correlate positively and significantly with insulin and HOMA. Among girls, the best anthropometric measure to identify adolescents with levels of insulin and HOMA above the 75th percentile was waist to height ratio: sensitivity was 66.7% (95% CI:59.4-73.9) for insulin and 60.2% (95% CI:52.7-67.8) for HOMA; specificity was 59.2% (95% CI:54.8-63.6) and 60.7% (95% CI:56.4-65.1), respectively. Among boys, the best anthropometric measure to identify those adolescents with levels of insulin and HOMA above the 75th percentile was body mass index: sensitivity was 66.4% (95% CI:58.9-74.0) for insulin and 65.6% (95% CI:58.0-73.1) for HOMA; specificity was 62.5% (95% CI:58.1-67.0) and 62.2 (95% CI:57.7-66.6) respectively.

Conclusions: Beyond BMI, waist to height ratio and waist circumference revealed to be accurate in the identification of adolescents at risk of alterations in the glucose metabolism.

INTRODUCTION

Adolescence has been referred as a critical period for development of obesity and co-morbidities associated with obesity in both sexes (1, 2), increasing the risk of mortality and morbidity in adulthood (2, 3). Body Mass Index (BMI) is the most common measure used to classify overweight. Nevertheless these classifications have to allow the identification of those adolescent in high risk to develop some diseases in a short or longer time.

Since BMI did not allow distinguish the effect of different types of body fat or different fat distribution, and each of them may have different impacts on health (4), other kind of anthropometric measures may help to the identification of adolescents at higher risk

In overweight and obese adolescents the most common pathology associated to overweight is insulin resistance and impaired insulin secretion (5, 6). Overweight and obesity are known risk factors for the increase of glycaemia and insulin resistance (7, 8). Worldwide, and in parallel with the increase on overweight incidence, the number of children and adolescents with type 2 diabetes mellitus is increasing (9). According to some authors, insulin resistance is the first detectable change in normoglycemic state and the increase of insulin levels may lead to fasting hyperglycaemia and the diagnosis of diabetes mellitus (10).

Abdominal obesity is associated with increased risk of metabolic disorders and insulin resistance (11-13). In adults, waist circumference, waist-to-height ratio and skinfold thickness seem to be good predictors of fasting plasma glucose and insulin (10, 14).

However, for adolescents, there is still a lack of information with respect of which measure and which cut-off values of the several adiposity measures best identify adolescents at risk of metabolic disorders like the glucose metabolism.

Thus, we intend to evaluate the ability of different adiposity measures to identify 13-year-old adolescents with high values of glucose, insulin and HOMA.

Participants and methods

During 2003/2004 school year, participants were selected as part of the assembling procedure of the Epiteen Cohort (15), which intends to follow adolescents born in 1990 and registered at every public and private schools of Porto, a large urban center in the north-west of Portugal. We identified 2787 eligible adolescents (2126 in public and 661 in private schools). Forty-four children (1.6%) could not be reached (missing classes during the study period), 584 (20.9%) were considered refusals since no signed informed consent form was returned, and 2160 (1651 public and 509 private school students) agreed to participate and provided information at least for part of the planned assessment. This resulted in a 77.5% overall participation proportion, similar in public (77.7%) and private schools (77.0%, p=0.709).

From the initial sample of 2160 adolescents, we exclude 210 adolescents with missing information in any of the anthropometric measures analyzed. The final sample included 1950 adolescents, with a girl's proportion of 51.5%. From this sample of 1950 adolescents, there were 1248 adolescents, 51.7% of girls, that had complete information on anthropometric data and analytic values.

The Ethical Committee of the Hospital of São João, Porto, approved the study. Parents and children received written information explaining the purpose and the design of the study. Additionally, the study steps were described in each school during special meetings arranged according to parents' convenience. Written informed consent was obtained both from parents and children.

The evaluation comprised two self-administered questionnaires (one completed at home, another at school), comprising information on demographic, social, and behavioral characteristics, and a physical examination performed at school, by a team of experienced nurses, nutritionists and physicians.

We considered the practice of sport activities when the participant was engaged in some physical leisure time activity performed on a repeated basis, spending at least 30 minutes a week and not included in the school curriculum. The parental education level was measured as the number of successfully completed years of formal schooling and we considered the parent with the highest education level.

Anthropometric measures and related indices

All measurements were obtained with the subject standing, in light indoor clothes and no shoes.

A digital scale (Tanita TBF-300) was used to measure the weight (in kilograms, to the nearest tenth) and the body fat percentage. The height was measured (in centimetres, to the nearest tenth) using a portable stadiometer.

Skinfolds Thickness

The skinfolds thickness was measured with a Harpenden calliper with a constant pressure of $10g/mm^2$. We measured a vertical pinch at the level of the mid-point between acromial process and proximal end of the radius bone, on the posterior surface of the arm for the tricipital and on the anterior surface of arm for the bicipital skinfold thickness (16).

Each skinfold was measured in the no dominant side of the body. We registered three measurements for each skinfold and considered the final result as the mean of them.

Waist Circumference

The circumferences were measured in centimeters (to the nearest tenth) with a flexible and non-distensible tape, avoiding exertion of pressure on the tissues and with the subject standing. The waist circumference was measured midway between the lower limit of the rib cage and the iliac crest, at the end of gentle expiration. The hip circumference was the maximal circumference over the femoral trochanters. The arm circumference was measured in the mid-point between acromial process and proximal end of the radius bone (17).

Body Mass Index (BMI)

Using the measured weight and height, BMI was calculated according to the formula $BMI=weight/height^2$. Then, according to the age- and sex-specific body mass index reference percentiles developed by the United States Centres for Disease Control and Prevention (18) participants were considered pre-obese if BMI was at or above 85th and below the 95^{th} percentile, and obese if BMI was at or above the 95^{th} percentile.

In the article and for the statistical analysis we considered participants with BMI at or above 85^{th} as overweight, gathering the two percentiles ($\geq 85^{th}$ and $\geq 95^{th}$), because the prevalence of obese participants (BMI $\geq 95^{th}$ percentile) was low.

Waist to height ratio

Waist to height ratio (WHtR) was calculated using the formula WHtR=waist/height, and based on the literature the 0.5 was used cut-off point for classifying adolescents (11).

Blood Samples and Analyses

A 12-hour overnight intravenous blood sample was taken from an antecubital vein. The fasting status was evaluated by the question “When was the last time you ate something?”

Blood was drawn into four vacuum tubes, two containing heparin, one containing EDTA and one with no additives. In the laboratory, the specimen were centrifuged, serum and plasma were divided into aliquots, and stored frozen at –80ºC until analysis, as was the case for insulin. Glucose was measured no more than three hours after blood collection. Blood glucose was measured using automatic standard routine enzymatic methods in use at the central pathology laboratory of the University Hospital of São João, Porto. Insulin was measured by radioimmunoassay (Coat-A-Count®, Diagnostic Products Corporation, Los Angeles, California, USA). Insulin resistance was assessed by the homeostasis model method (HOMA-IR), based on fasting glucose and insulin concentrations: HOMA-IR=Insulin (mU/ml)*glucose (mmol/L)/22.5 (19).

Statistical Analysis

Statistical analysis was performed using SPSS®, version 17.0 (SPSS Inc, Chicago, Illinois). We used the Wilcoxon-Mann-Whitney to compare averages.

To examine relations between each anthropometric measurements and serum levels of glucose, insulin and HOMA, we used the Spearman correlation coefficient. A significant level of 0.05 was assumed.

Receiver-operating characteristic (ROC) curve analyses were used to analyse the potential diagnostic accuracy of the different measures of adiposity to discriminate between low and high insulin, glucose and HOMA, assuming the 75th percentile as cut-off (20).

The area under the curve (AUC) is also presented. The AUC represents the ability of the anthropometric measure tested to correctly classify the adolescents with values above the 75^{th} percentile of insulin (11.46 for girls and 9.22 for boys), glucose (0.90 for girls and 0.91 for boys) and HOMA $\geq 75^{th}$ percentile (0.43 for girls and 0.36 for boys).

We calculated the diagnostic value of the different measures of adiposity considering the cut-offs that maximized the sensibility and specificity, and then using the cut-offs that were previously determined, using BMI as reference for the identification of overweight.

RESULTS

In our sample the prevalence of adolescents that reported to practice sports was low, namely in girls. The prevalence of overweight was 12.5%. There were not significant differences between participants and those excluded from the analysis, except for parent's education ($p<0.001$), parents from the participant adolescents had more years of completed education than those from the excluded ones *(Table 1).*

Table 2 shows correlation coefficients between biceps skinfolds, triceps skinfolds, body fat percentage, BMI, waist circumference and waist to height ratio, with insulin, glucose and HOMA, by gender. In both sexes all of the anthropometric measurements correlate positively and significantly with insulin and HOMA. The weakest correlation coefficients were found between glucose and the anthropometric measures evaluated for boys and girls.

In *Table 3* we present sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and positive and negative likelihood ratio (PLR and NLR) of each anthropometric measure to identify girls in the $\geq 75^{th}$ percentile for the analytic values considered. Among girls, the best anthropometric measure to identify insulin and HOMA levels within or above this percentile was waist to height ratio. Sensitivity was 66.7% (95% CI:59.4-73.9) for insulin and 60.2% (95% CI:52.7-67.8) for HOMA; specificity was 59.2% (95% CI:54.8-63.6) and 60.7% (95% CI:56.4-65.1), respectively. In *Table 4* we present sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and positive and negative likelihood ratio (PLR and NLR) of each anthropometric measure to identify boys in the $\geq 75^{th}$ percentile for the analytic values considered. Among boys the best anthropometric measure was BMI; sensitivity was 66.4% (95% CI:58.9-74.0) for insulin and 65.6% (95% CI:58.0-73.1) for HOMA; specificity was 62.5% (95% CI:58.1-67.0) and 62.2 (95% CI:57.7-66.6), respectively.

Considering the glucose levels, in both sexes all of the anthropometric measurements revealed lower sensitivity and specificity to identify it (table 3 and table 4). The most accurate anthropometric measure to identify high glucose levels in adolescents was waist circumference; sensitivity was 63.4% (95% CI:56.2-70.6) and specificity was 37.8%(95% CI:33.5-42.2) among girls. Among boys sensitivity was 56.2% (95% CI:48.3-64.1) and specificity was 50.7% (95% CI:46.0-55.3).

When compared the sensitivity and specificity from the sample cut-offs with the ones calculated previously has the ones that identified overweight adolescents, the cut-offs previously defined were less sensitive, more specific and with lower values, than those from de sample.

DISCUSSION

Our data showed that waist to height ratio is a sensitive tool to identify girls with high levels (≥75th percentile) of insulin and HOMA. Its specificity can be enhanced by the evaluation of biceps skinfold for insulin and waist to height ratio for HOMA.

Among boys the anthropometric measure that reveled to be most sensitive identifying participants with high levels of insulin and HOMA was BMI, and its specificity can be improved by the evaluation of the waist circumference and body fat percentage.

Our data are in accordance with other studies waist circumference to height ratio, waist circumference and BMI to be accurate measures to identify adolescents with higher serum levels of insulin and HOMA (10, 11, 13, 21).

Also skinfolds thicknesses were accurate measures to identify adolescents with worse metabolic risk profile (14, 21). However, the small increment in specificity balanced with the effort to perform the thicknesses and the necessity of a strong training to reduce error between interviewers, did not support the utilization of this kind of measures in studies with large sample sizes. Nevertheless they could be useful to a better understand the role of subcutaneous fat.

Since our sample was population-based the prevalence of diabetes was low. Nevertheless, Diabetes' related complications are a result of a continuous exposure to high plasma glucose values so, even those with impaired fasting glucose or impaired glucose tolerance have an increased risk of adverse outcomes and, since more young individuals develop this profile, greater is their propensity to develop those complications (22-23). So, we decided to use the 75th percentile to classify adolescents in higher risk to develop disease. This assumption can be conservative because some of the adolescents with values above this percentile and classified as in higher risk, have low risk to develop a disease.

As weaknesses in our study we have the fact that glucose assays were only run once, not in duplicate: a systematic review which assessed the reproducibility of impaired fasting glucose in adults showed that the k coefficients indicated only a moderate agreement for impaired fasting glucose (0.44 and 0.56) (24). An oral glucose tolerance test could add some information. However, it would be impossible to perform an oral glucose tolerance test on such a large sample and reduce the sample could affect the external validity.

A major strength of our study is its relatively large sample size, which was taken from a nonclinical population. In Portugal, education is mandatory till 15-year-old, so recruiting 13-year-old adolescents from school gave us the better sample basis. Besides, we have a good rate of participation and there were almost no differences between those participants not considered in the analyses and those with complete information, which minimizes a possible selection bias. Therefore, we have a high confidence that our results give a good perspective of our teenage population. One other aspect is the homogeneity regarding age, since to take into account that variability, a very large sample would be necessary (25-26).

In adolescents there is an additional difficulty regarding the identification of the correct diagnostic cutoff value of metabolic disorders, because of the variability that exists on expect normal values trough growth and development (27).

With this study we expect to bring a contribution to the standardization of procedures to identify overweight adolescents and those at higher risk to develop obesity or some related consequences later in life.

REFERENCES

1. Daniels SR, Arnett DK, Eckel RH, Gidding SS, Hayman LL, Kumanyika S, et al. Overweight in children and adolescents: pathophysiology, consequences, prevention, and treatment. Circulation. 2005 Apr 19;111(15):1999-2012.

2. Flodmark CE, Lissau I, Moreno LA, Pietrobelli A, Widhalm K. New insights into the field of children and adolescents' obesity: the European perspective. Int J Obes Relat Metab Disord. 2004 Oct;28(10):1189-96

3. Lissau I, Overpeck MD, Ruan WJ, Due P, Holstein BE, Hediger ML. Body mass index and overweight in adolescents in 13 European countries, Israel, and the United States. Arch Pediatr Adolesc Med. 2004 Jan;158(1):27-33

4. Ferreira I, Twisk JW, van Mechelen W, Kemper HC, Seidell JC, Stehouwer CD. Current and adolescent body fatness and fat distribution: relationships with carotid intima-media thickness and large artery stiffness at the age of 36 years. J Hypertens. 2004 Jan;22(1):145-55.

5. Keskin M, Kurtoglu S, Kendirci M, Atabek ME, Yazici C. Homeostasis model assessment is more reliable than the fasting glucose/insulin ratio and quantitative insulin sensitivity check index for assessing insulin resistance among obese children and adolescents. Pediatrics. 2005 Apr;115(4):e500-3.

6. Silink M. Childhood diabetes: a global perspective. Horm Res. 2002;57 Suppl 1:1-5.

7. Libman IM, Arslanian SA. Prevention and treatment of type 2 diabetes in youth. Horm Res. 2007;67(1):22-34.

8. Velasco-Martínez RM, Jiménez-Cruz A, Higuera Domínguez F, Domínguez de la Piedra E, Bacardí-Gascón M. Obesidad y resistencia a la insulina en adolescentes de chiapas. Nutr Hosp. 2009 Mar-Apr;24(2):187-92.

9. Gungor N, Hannon T, Libman I, Bacha F, Arslanian S. Type 2 diabetes mellitus in youth: the complete picture to date. Pediatr Clin North Am. 2005 Dec;52(6):1579-609.

10. Ford ES, Li C. Defining the metabolic syndrome in children and adolescents: will the real definition please stand up? J Pediatr. 2008 Feb;152(2):160-4.

11. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0·5 could be a suitable global boundary value. Nutr Res Rev. 2010 Dec;23(2):247-69.

12. Johnson WD, Kroon JJ, Greenway FL, Bouchard C, Ryan D, Katzmarzyk PT. Prevalence of risk factors for metabolic syndrome in adolescents: National Health and Nutrition Examination Survey (NHANES), 2001-2006. Arch Pediatr Adolesc Med. 2009 Apr;163(4):371-7.

13. Freedman DS, Sherry B. The validity of BMI as an indicator of body fatness and risk among children. Pediatrics. 2009 Sep;124 Suppl 1:S23-34

14. Sievenpiper JL, Jenkins DJ, Josse RG, Leiter LA, Vuksan V. Simple skinfold thickness measurements complement conventional anthropometric assessments in predicting glucose tolerance. Am J Clin Nutr. 2001 Mar;73(3):567-73.

15. Ramos E, Barros H. Family and school determinants of overweight in adolescents. Acta Paediatr. 2007 Feb;96(2):281-6.

16. Gibson RS. Principles of nutricional assessment.2nd ed. New York: Oxford University Press; 2005.

17. World Health Organization. Measuring Obesity: Classification and Description of Anthropometric Data. Report on a WHO Consultation on the Epidemiology of Obesity. Copenhagen, Denmark: WHO Regional Office for Europe, Nutrition Unit; 1988.

18. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC growth charts for the United States: methods and development. Vital Health Stat 11. 2002 May; (246): 1-190.

19. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia. 1985 Jul;28(7):412-9

20. Hanley JA. The robustness of the"binominal" assumptions used in fitting ROC curves. Med Decis Making. 1988 Jul-Sep;8(3):197-203.

21. Freedman DS, Serdula MK, Srinivasan SR, Berenson GS. Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: the Bogalusa Heart Study. Am J Clin Nutr. 1999 Feb;69(2):308-17.

22. Reinehr T, Kiess W, de Sousa G, Stoffel-Wagner B, Wunsch R. Intima media thickness in childhood obesity: relations to inflammatory marker, glucose metabolism, and blood pressure. Metabolism. 2006 Jan;55(1):113-8.

23. WHO. Definition and diagnosis of diabetes mellitus and intermediate hyperglycemia: report of a WHO/IDF consultation. Geneva: World Health Organization2006.

24. Balion CM, Raina PS, Gerstein HC, Santaguida PL, Morrison KM, Booker L, et al. Reproducibility of impaired glucose tolerance (IGT) and impaired fasting glucose (IFG) classification: a systematic review. Clin Chem Lab Med. 2007;45(9):1180-5.

25. Marrodán Serrano MD, Mesa Santurino MS, Alba Díaz JA, Ambrosio Soblechero B, Barrio Caballero PA, Drak Hernández L, et al. Diagnosis de la obesidad: actualización de criterios y su validez clínica y poblacional. Na Pediatr (Barc). 2006 Jul;65(1):5-14.

26. Singh AS, Chin A Paw MJ, Brug J, van Mechelen W. Dutch obesity intervention in teenagers: effectiveness of a school-based program on body composition and behavior. Arch Pediatr Adolesc Med. 2009 Apr;163(4):309-17.

27. Goodman E, Daniels SR, Meigs JB, Dolan LM. Instability in the diagnosis of metabolic syndrome in adolescents. Circulation. 2007 May 1;115(17):2316-22.

Table 1: Sample characteristics according to subjects included and excluded from the analyses.

	n(%)		
	Participants	**Excluded**	p-value
Parents education (years)			
0 – 6	842(36.1)	548(40.4)	**<0.001**
7 – 9	470(20.1)	324(23.9)	
10 – 12	549(23.5)	252(18.7)	
>12	475(20.)	231(17.0)	
Missing	160	50	
Gender			
Boys	603 (48.3)	344(48.9)	0.83
Girls	645(51.7)	358(51.1)	
Practice of sports activity			
Yes	565(50.0)	273(50.3)	0.94
No	564(50.0)	275(49.7)	
Missing	119	154	
BMI (kg/m^2)			
<85th percentile	1092(85.5)	621(88.5)	0.52
85-95th percentile	126(10.1)	67(9.5)	
≥95th percentile	30(2.4)	14(2.0)	
	Mean (standard deviation)		p-value
Biceps Skinfold (mm)			
Average(sd)	7.4±(3.74)	7.5±(3.94)	0.85
Triceps Skinfold (mm)			
Average(sd)	13.4±(5.16)	13.3±(5.20)	0.48
% Body Fat			
Average(sd)	20.9±(9.47)	20.1±(9.39)	0.096
Waist to Height Ratio			
Average(sd)	0.45±(0.05)	0.45±(0.05)	0.37
Waist Circumference			
Average(sd)	72.5±(8.6)	71.9±(8.9)	0.14

Table 2: Correlation coefficients between Biceps skinfolds, Triceps skinfolds, % Body fat, BMI, Waist circumference and Waist to height ratio, with insulin, glucose and HOMA by gender

	Boys											
	Correlation coeficient (95% IC)											
	Biceps skinfold		Triceps skinfold		% Body Fat		BMI		Waist circumference		Waist to height ratio	
Glucose	-0.04	[-0.12;0.04]	-0.01	[-0.01;0.07]	0.01	[-0.07;0.09]	0.04	[-0.04;0.12]	0.03	[-0.05;0.11]	-0.01	[-0.09;0.07]
Insulin	0.30	[0.23;0.37]	0.28	[0.21;0.36]	0.31	[0.24;0.38]	0.33	[0.25;0.40]	0.33	[0.26;0.40]	0.29	[0.21;0.36]
HOMA	0.29	[0.21;0.36]	0.27	[0.19;0.35]	0.31	[0.23;0.38]	0.32	[0.25;0.39]	0.33	[0.25;0.40]	0.28	[0.21;0.35]
	Girls											
	Correlation coeficient (95% IC)											
	Biceps skinfold		Triceps skinfold		% Body Fat		BMI		Waist circumference		Waist to height ratio	
Glucose	-0.04	[-0.11;0.04]	-0.03	[-0.11;0.05]	-0.01	[-0.08;0.07]	-0.03	[-0.10;0.05]	-0.01	[-0.08;0.07]	-0.02	[-0.09;0.06]
Insulin	0.25	[0.18;0.32]	0.19	[0.12;0.27]	0.26	[0.17;0.38]	0.27	[0.20;0.34]	0.29	[0.22;0.36]	0.29	[0.22, 0.36]
HOMA	0.24	[0.16;0.31]	0.18	[0.11;0.26]	0.23	[0.16;0.31]	0.25	[0.18;0.32]	0.28	[0.20;0.35]	0.28	[0.20;0.35]

Table 3: Diagnostic value of the different measures of adiposity in detecting high levels (≥75th percentile), of glucose, insulin and HOMA, for girls

	Glucose		*Insulin*		*HOMA*	
	Previous cut-off	**Sample cut-off**	**Previous cut-off**	**Sample cut-off**	**Previous cut-off**	**Sample cut-off**
Biceps Skinfold						
Cut-off *(mm)*	9.1	7.2	9.1	7.9	9.1	7.9
Sensitivity (95% CI)	27.4(20.8;34.8)	53.5(46.0;60.9)	45.0(37.1;53.0)	59.3(51.7;66.8)	41.3(33.5-49.3)	55.9(48.2;63.6)
Specificity (95% CI)	70.1(66.5;74.9)	47.6(43.1;52.1)	76.7(72.7;80.4)	63.6(59.3;67.9)	75.5(71.4-79.3)	62.4(58.1;66.7)
PPV (95% CI)	25.0(18.9;31.9)	27.1(22.3;31.8)	39.1(32.0;46.6)	35.3(29.6;41.0)	35.9(28.9-43.3)	33.1(27.5;38.7)
NPV (95% CI)	73.3(69.0;77.3)	73.8(68.8;78.7)	80.7(76.8;84.3)	82.3(78.4;86.2)	79.4(75.4-83.0)	81.0(77.0;85.0)
PLR (95% CI)	0.9(0.7;1.2)	1.0(0.9;1.2)	1.9(1.5;2.4)	1.6(1.4;1.9)	1.7(1.3-2.1)	1.5(1.2;1.8)
NLR (95% CI)	1.02(0.9;1.14)	1.0(0.8;1.2)	0.7(0.6;0.8)	0.6(0.5;0.8)	0.8(0.7-0.9)	0.7(0.6;0.9)
AUC	0.518	0.485	0.658	0.652	0.620	0.622
Triceps Skinfold						
Cut-off *(mm)*	17.9	9.4	17.9	17.4	17.9	17.4
Sensitivity (95% CI)	23.8(17.6;31.0)	54.9(47.0;62.8)	38.8(31.2;46.8)	52.5(44.8;60.2)	35.6(28.2-43.4)	52.2(44.5;59.9)
Specificity (95% CI)	72.3(68.0;76.3)	47.1(42.5;51.7)	77.3(73.3;81.0)	61.7(57.4;66.0)	76.3(72.2-80.0)	61.6(57.2;65.9)
PPV (95% CI)	23.4 (17.3;30.5)	26.1(21.3;30.9)	36.3(29.1;43.9)	31.5(25.9;37.0)	33.3(26.3-40.9)	31.1(25.6;36.6)
NPV (95% CI)	72.8(68.5;76.7)	75.4(70.4;80.5)	79.1(75.2;82.7)	79.5(75.4;83.6)	78.1(74.1-81.8)	79.5(75.4;83.6)
PLR (95% CI)	0.9(0.6;1.2)	1.0(0.9;1.2)	1.7(1.3;2.2)	1.4(1.1;1.7)	1.5(1.2-2.0)	1.4(1.1;1.6)
NLR (95% CI)	1.1(1.0;1.2)	1.0(0.8;1.2)	0.8(0.7;0.9)	0.8(0.7;0.9)	0.8(0.7-1.0)	0.8(0.7;0.9)
AUC	0.525	0.512	0.612	0.618	0.596	0.610
Percentage of Body Fat						
Cut-off *(%)*	30	13.0	30.0	28.0	30.0	28.0
Sensitivity (95% CI)	28.6(21.9;36.0)	52.3(44.4;60.2)	47.5(39.6;55.5)	53.7(46.0;61.4)	44.4(36.5;52.4)	52.8(45.1;60.5)
Specificity (95% CI)	68.1(63.7;72.3)	51.1(46.5;55.7)	74.4(70.2;78.3)	62.7(58.4;67.0)	73.4(69.2;77.3)	62.4(58.1;66.7)
PPV (95% CI)	24.1(18.4;30.7)	26.7(21.7,31.7)	38.2(31.4;45.3)	32.6(27.0;38.2)	35.7(29.0;42.8)	31.8(26.2;37.4)
NPV (95% CI)	72.9(68.5;76.9)	75.9(71.1;80.7)	81.0(77.0;84.5)	80.2(76.1;84.2)	79.9(75.8;83.5)	79.9(75.9;83.9)
PLR (95% CI)	0.9(0.7;1.2)	1.07(0.9;1.23)	1.9(1.5;2.3)	1.4(1.2;1.7)	1.7(1.3;2.1)	1.4(1.2;1.7)
NLR (95% CI)	1.0(0.9;1.2)	1.0(0.8;1.1)	0.7(0.6;0.8)	0.7(0.6;0.9)	0.8(0.7;0.9)	0.8(0.6; 0.9)
AUC	0.525	0.512	0.629	0.635	0.608	0.623
Waist Circumference						
Cut-off *(cm)*	72.5	71.0	72.5	71.1	72.5	71.3
Sensitivity (95% CI)	36.9(29.6;44.7)	56.2(48.3;64.1)	51.3(43.2;59.2)	58.6(51.1;66.2)	47.5(39.6;55.6)	54.0(46.3;61.7)
Specificity (95% CI)	63.9(59.3;68.2)	50.7(46.0;55.3)	68.6(64.3;72.7)	61.1(56.7;65.4)	67.4(63.0;71.5)	61.2(56.8;65.5)
PPV (95% CI)	26.6(21.1;32.8)	27.9(22.9;32.9)	35.2(29.1;41.7)	33.6(28.1;39.1)	32.6(26.6;39.0)	31.6(26.1;37.1)
NPV (95% CI)	74.0(69.5;78.2)	77.3(72.5;82.1)	80.8(76.7;84.6)	81.5(77.5;85.5)	79.4(75.2;83.2)	80.0(75.9;84.1)
PLR (95% CI)	1.0(0.8;1.3)	1.1(1.0; 1.4)	1.6(1.3;2.0)	1.5(1.3;1.8)	1.5(1.2;1.8)	1.4(1.2; 1.7)
NLR (95% CI)	1.0(0.9;1.1)	1.0(0.7;1.1)	0.7(0.6;0.8)	0.7(0.6;0.8)	0.8(0.7;0.9)	0.8(0.6;0.9)
AUC	0.505	0.526	0.656	0.655	0.631	0.638
Waist to Height ratio						
Cut-off	0.48	0.4	0.48	0.5	0.48	0.5
Sensitivity (95% CI)	22.6(16.5;29.7)	53.6(45.7;61.5)	42.5(34.7;50.6)	66.7(59.4;73.9)	39.4(31.8;47.4)	60.2(52.7;67.8)
Specificity (95% CI)	74.6(70.5;78.5)	45.8(41.2;50.4)	81.3(77.5;84.7)	59.2(54.8;63.6)	80.2(76.4;83.7)	60.7(56.4;65.1)
PPV (95% CI)	24.1(17.6;31.5)	25.2(20.4;29.9)	43.0(35.2;51.1)	35.4(30.0;40.8)	39.9(32.2;48.0)	33.8(28.3;39.3)
NPV (95% CI)	73.1(68.9;77.0)	74.3(69.2;79.5)	81.0(77.2;84.4)	84.1(80.2;88.0)	79.9(76.1;83.4)	82.1(78.2;86.1)
PLR (95% CI)	0.9(0.6;1.2)	1.0(0.8;1.2)	2.3(1.8;2.9)	1.6(1.4;1.9)	2.0(1.5;2.6)	1.5(1.3;1.8)
NLR (95% CI)	1.0(0.9;1.1)	1.0(0.8;1.2)	0.7(0.6;0.8)	0.6(0.5; 0.7)	0.8(0.7;0.9)	0.7(0.5;0.8)
AUC	0.517	0.506	0.668	0.661	0.638	0.641
BMI						
Cut-off	P≥85th	19.7	P≥85th	20.8	P≥85th	20.9
Sensitivity (95% CI)	22.6(16.5;29.7)	55.6(47.7;63.4)	43.8(35.9;51.8)	57.4(49.8;65.0)	38.8(31.1;46.8)	54.0(46.3;61.7)
Specificity (95% CI)	75.7(71.6;79.5)	45.1(40.5;49.7)	82.7(79.1;86.0)	60.5(56.1;64.8)	81.0(77.2;84.5)	60.5(56.2;64.9)
PPV (95% CI)	24.9(18.2;32.5)	25.6(20.9;30.3)	45.8(37.7;54.0)	32.7(27.3;38.2)	40.5(32.7;48.7)	31.3(25.8;36.7)
NPV (95% CI)	73.4(69.2;77.2)	74.9(69.7;80.1)	81.6(77.8;84.9)	80.9(76.8;84.9)	79.9(76.1;83.4)	79.8(75.7;83.9)
PLR (95% CI)	0.9(0.7;1.3)	1.0(0.9;1.2)	2.5(1.9;3.3)	1.5(1.2;1.7)	2.0(1.6;2.7)	1.4(1.1;1.6)
NLR (95% CI)	1.0(0.9;1.1)	1.0(0.8;1.2)	0.7(0.6;0.8)	0.7(0.6;0.9)	0.8(0.7;0.9)	0.8(0.6;0.9)
AUC	0.508	0.520	0.632	0.649	0.599	0.623

PPV- Positive predictive value; **NPV-** Negative predictive value; **PLR-** Positive likelihood ratio; **NLR**- Negative likelihood ratio; **AUC-**Area under the curve

Table 4: Diagnostic value of the different measures of adiposity in detecting high levels (≥75th percentile), of glucose, insulin and HOMA, for boys

	Glucose		*Insulin*		*HOMA*	
	Previous cut-off	**Sample cut-off**	**Previous cut-off**	**Sample cut-off**	**Previous cut-off**	**Sample cut-off**
Biceps Skinfold						
Cut-off *(mm)*	6.5	5.2	6.5	5.9	6.5	6.0
Sensitivity (95% CI)	41.6(33.6;50.0)	55.6(47.7;63.4)	60.4(52.1;68.3)	65.1(57.6;72.7)	59.1(50.7;67.0)	60.9(53.1;68.7)
Specificity (95% CI)	61.2(56.6;65.8)	46.9(42.3;51.5)	67.5(62.9;71.8)	60.3(55.8;64.8)	67.0(62.5;71.4)	61.5(57.0;66.0)
PPV (95% CI)	26.3(20.8;32.4)	26.2(21.4;31.0)	38.1(31.9;44.7)	35.6(30.0;41.2)	37.3(31.1;43.8)	34.6(28.9;40.3)
NPV (95% CI)	76.0(71.2;80.3)	75.6(70.6;80.7)	83.7(79.5;87.4)	83.7(79.7;87.7)	83.1(78.9;86.9)	82.5(78.4;86.6)
PLR (95% CI)	1.1(0.9;1.3)	1.1(0.9;1.2)	1.9(1.5;2.2)	1.6(1.4;1.9)	1.8(1.5;2.2)	1.6(1.3;1.9)
NLR (95% CI)	1.0(0.8;1.1)	1.0(0.8;1.2)	0.6(0.5;0.7)	0.6(0.5;0.7)	0.6(0.5;0.7)	0.6(0.5;0.8)
AUC	0.505	0.495	0.682	0.684	0.675	0.675
Triceps Skinfold						
Cut-off *(mm)*	11.2	9.4	11.2	10.5	11.2	10.7
Sensitivity (95% CI)	41.6(33.6;50.0)	54.9(47.0;62.8)	57.7(49.3;65.8)	65.1(57.6;72.7)	55.0(46.7;63.2)	60.3(52.5;68.1)
Specificity (95% CI)	59.2(54.5;63.8)	47.1(42.5;51.7)	64.6(60.1;69.0)	60.5(56.0;65.0)	63.7(59.1;68.2)	60.4(55.9;64.9)
PPV (95% CI)	25.3(20.0;31.2)	26.1(21.3;30.9)	35.1(29.1;41.4)	35.7(30.1;41.4)	33.5(27.6;39.8)	33.7(28.1;39.3)
NPV (95% CI)	75.4(70.5;79.8)	75.4(70.4;80.5)	82.1(77.8;86.0)	83.7(79.7;87.7)	81.0(76.5;85.0)	82.0(77.9;86.1)
PLR (95% CI)	1.0(0.8;1.3)	1.0(0.9;1.2)	1.6(1.4;2.0)	1.7(1.4;2.0)	1.5(1.3;1.8)	1.5(1.3;1.8)
NLR (95% CI)	1.0(0.8;1.2)	1.0(0.8;1.2)	0.7(0.5;0.8)	0.6(0.5;0.7)	0.7(0.6;0.9)	0.7(0.5;0.8)
AUC	0.506	0.512	0.672	0.680	0.655	0.659
Percentage of Body Fat						
Cut-off *(%)*	15.9	13.0	15.9	13.5	15.9	13.8
Sensitivity (95% CI)	36.9(29.2;45.2)	52.3(44.4;60.2)	57.8(49.4;65.8)	65.8(58.2;73.3)	55.0(46.7;63.2)	61.6(53.8;69.3)
Specificity (95% CI)	66.4(61.8;70.7)	51.1(46.5;55.7)	73.3(68.9;77.3)	60.3(55.8;64.8)	72.4(68.0;76.5)	60.6(56.1;65.1)
PPV (95% CI)	26.7(20.8;33.3)	26.7(21.7;31.7)	41.7(34.9;48.8)	35.8(30.2;41.5)	39.8(33.1;46.8)	34.3(28.7;40.0)
NPV (95% CI)	76.0(71.5;80.2)	75.9(71.1;80.7)	83.9(79.9;87.4)	84.0(80.0;87.9)	82.9(78.8;86.5)	82.5(78.4;86.6)
PLR (95% CI)	1.1(0.9;1.4)	1.1(0.9;1.2)	2.2(1.8;2.7)	1.7(1.4;2.0)	2.0(1.2;2.5)	1.6(1.3;1.9)
NLR (95% CI)	1.0(0.8;1.1)	1.0(0.8;1.1)	0.6(0.5;0.7)	0.6(0.5;0.7)	0.6(0.5;0.8)	0.6(0.5;0.8)
AUC	0.512	0.512	0.685	0.694	0.666	0.671
Waist Circumference						
Cut-off *(cm)*	75.5	71.0	75.5	71.6	75.5	71.8
Sensitivity (95% CI)	36.2(28.5;44.5)	56.2(48.3;64.1)	50.3(42.0;58.6)	66.4(58.9;74.0)	48.3(40.1;56.7)	64.2(56.6;71.9)
Specificity (95% CI)	69.5(65.0;73.7)	50.7(46.0;55.3)	74.2(69.9;78.2)	60.3(55.8;64.8)	73.5(69.2;77.5)	60.2(55.7;64.7)
PPV (95% CI)	28.3(22.0;35.2)	27.9(22.9;32.9)	39.3(32.3;46.6)	36.1(30.4;41.7)	37.7(30.8;45.0)	35.0(29.4;40.6)
NPV (95% CI)	76.7(72.2;80.7)	77.3(72.5;82.1)	81.8(77.7;85.4)	84.2(80.2;88.2)	81.1(76.9;84.8)	83.4(79.4;87.5)
PLR (95% CI)	1.2(0.9;1.5)	1.1(1.0; 1.4)	1.9(1.6;2.4)	1.7(1.4;2.0)	1.8(1.5;2.3)	1.6(1.4;1.9)
NLR (95% CI)	0.9(0.8;1.1)	1.0(0.7;1.1)	0.7(0.6;0.8)	0.6(0.4,0.7)	0.7(0.6;0.8)	0.6(0.5;0.8)
AUC	0.527	0.526	0.678	0.681	0.666	0.666
Waist to Height ratio						
Cut-off	0.46	0.4	0.46	0.4	0.46	0.4
Sensitivity (95% CI)	31.5(24.2;39.7)	53.6(45.7;61.5)	49.0(40.7;57.3)	59.2(51.4;67.0)	46.3(38.1;54.7)	56.3(48.4;64.2)
Specificity (95% CI)	67.5(62.9;71.8)	45.8(41.2;50.4)	73.3(68.9;77.3)	63.0(58.5;67.4)	72.4(68.0;76.5)	61.9(57.5;66.4)
PPV (95% CI)	24.4(18.5;31.0)	25.2(20.4;29.9)	37.8(31.0;45.1)	35.0(29.2;40.9)	35.8(29.0;43.0)	33.1(27.3;38.8)
NPV (95% CI)	74.8(70.3;79.0)	74.3(69.2;79.5)	81.2(77.1;84.9)	82.1(78.0;86.1)	80.2(76.0;84.0)	80.9(76.7;85.1)
PLR (95% CI)	1.0(0.7;1.3)	1.0(0.8;1.2)	1.8(1.5;2.3)	1.6(1.3;1.9)	1.7(1.3;2.1)	1.5(1.2;1.8)
NLR (95% CI)	1.0(0.9;1.2)	1.0(0.8;1.2)	0.7(0.6;0.8)	0.7(0.5;0.8)	0.7(0.6;0.9)	0.7(0.6;0.9)
AUC	0.505	0.506	0.639	0.645	0.623	0.625
BMI						
Cut-off	P≥85th	19.7	P≥85th	20.4	P≥85th	20.4
Sensitivity (95% CI)	32.2(24.9;40.4)	55.6(47.7;63.4)	43.6(35.5;52.0)	66.4(58.9;74.0)	42.3(34.2;50.6)	65.6(58.0;73.1)
Specificity (95% CI)	75.1(70.8;79.0)	45.1(40.5;49.7)	78.8(74.8;82.5)	62.5(58.1;67.0)	78.4(74.3;82.1)	62.2(57.7;66.6)
PPV (95% CI)	30.0(23.0;37.7)	25.6(20.9;30.3)	40.6(32.9;48.7)	37.4(31.6;43.2)	39.4(31.8;47.4)	36.7(30.9;42.4)
NPV (95% CI)	76.9(72.7;80.8)	74.9(69.7;80.1)	80.8(76.8;84.4)	84.7(80.8;88.6)	80.4(76.3;84.0)	84.3(80.5;88.3)
PLR (95% CI)	1.3(1.0;1.7)	1.0(0.9;1.2)	2.1(1.6;2.7)	1.7(1.5;2.1)	2.0(1.5;2.5)	1.7(1.5;2.0)
NLR (95% CI)	0.9(0.8;1.0)	1.0(0.8;1.2)	0.7(0.6;0.8)	0.5(0.4;0.7)	0.7(0.6;0.9)	0.6(0.4;0.7)
AUC	0.536	0.520	0.612	0.695	0.603	0.683

PPV- Positive predictive value; **NPV-** Negative predictive value; **PLR-** Positive likelihood ratio; **NLR**- Negative likelihood ratio; **AUC-**Area under the curve

CONCLUSIONS

This research based in a population-based sample of Portuguese adolescents allowed reaching to the following conclusions:

Waist circumference was a sensitive and specific tool for the detection of overweight in adolescents. Additionally, the specificity of this measure may be improved by the use of the waist to height ratio. In contrast, skinfolds measurements presented a very low accuracy to identify overweight in this age group.

For all adiposity measures the cut-offs based on the literature presented a higher AUC than those based in our specific cut-offs, supporting the use of the same cut-offs in different populations, allowing investigators to compare data from different cross-sectional prevalence studies.

Regarding the identification of adolescents with risk of alteration in the glucose metabolism, among girls waist to height ratio is a sensitive tool to identify girls with high levels (≥75th percentile) of insulin and HOMA. Its specificity can be enhanced by the evaluation of biceps skinfold for insulin and waist to height ratio for HOMA.

These findings help to understand how cheap and easy to access anthropometric measurements can contribute to the identification of overweight 13 year old adolescents and to identify the ones with high values of glucose, insulin and HOMA. Data presented in this work contributes to the standardization of procedures to identify overweight in adolescents and its consequences.